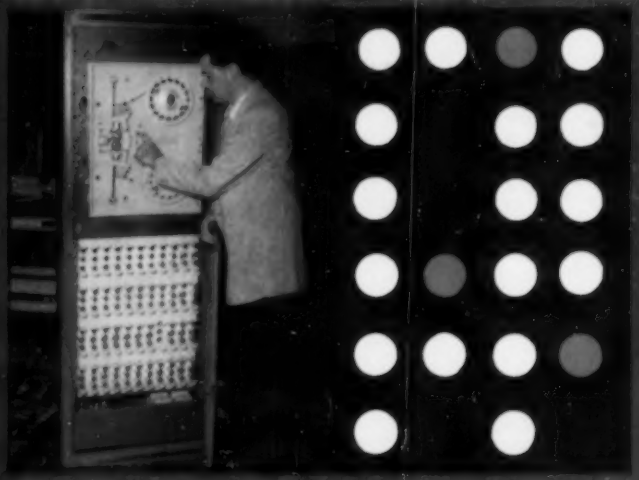
CEP
CHEMICAL ENGINEERING PROGRESS
NOVEMBER 1956

WHAT'S BEING DONE WITH



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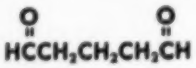
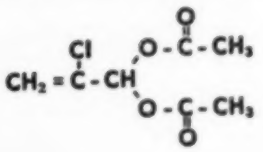


- a new reactive monomer—presence of chlorine group in the molecule enhances copolymerization with such materials as vinyl chloride

2-CHLORALLYLIDENE DIACETATE



PHYSICAL PROPERTIES	Pentanediol	Glutaraldehyde (30% solution)	2-Chlorallylidene Diacetate
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Specific Gravity at 20/20°C	0.9919	1.074	1.213
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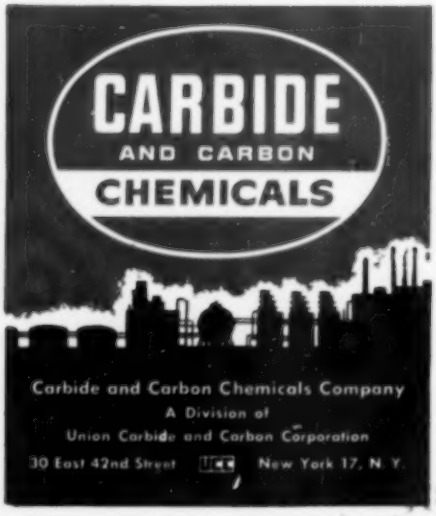

Chemical Engineering Progress

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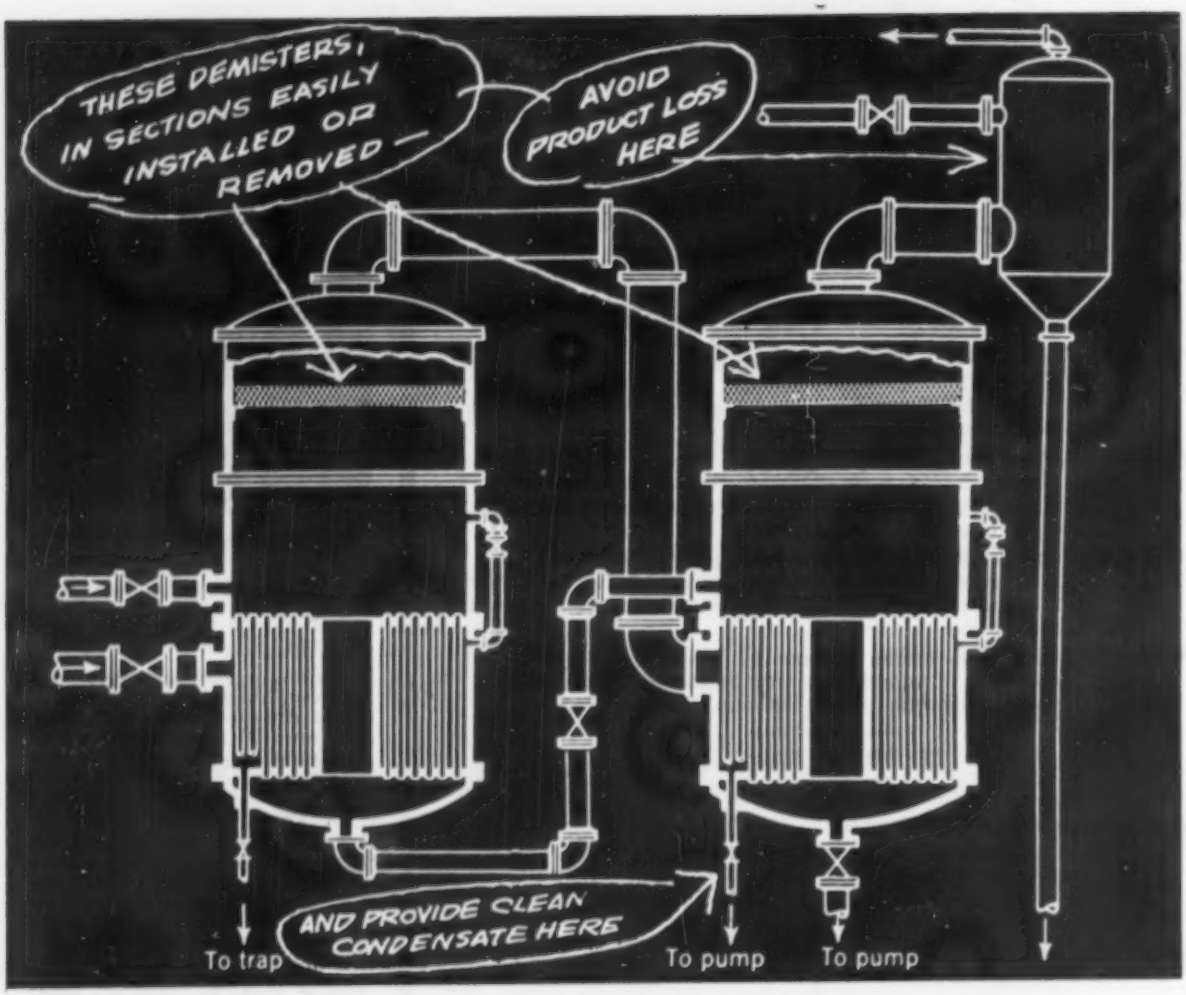

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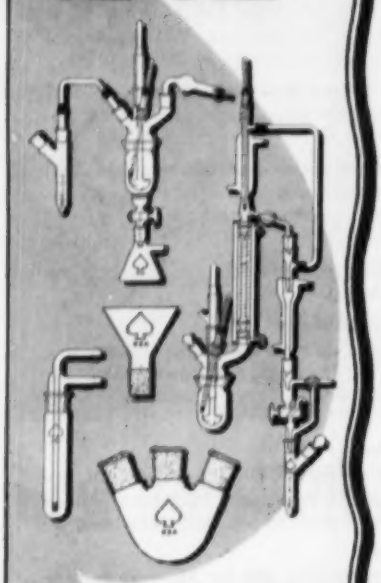

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Letters to the editor

Getting straight about the

Economics of Atomic Power

How much will it cost to generate electric power in the first large-scale nuclear power plants? In the following communication, reader W. Kenneth Davis, director of Reactor Development for the A.E.C., as well as a member of A.I.Ch.E. and a director of its Nuclear Energy Division, sets the record straight in the light of the confusing statements appearing in the press.

I thought that the September 1956 issue of *Chemical Engineering Progress* was excellent and demonstrated the vital contributions of chemical engineering to the atomic energy field. However, your editorial on the "Economics of Atomic Power" [Mr. Davis is referring to "Trends," p. 77.—Ed.] showed a lack of understanding of the facts and can only serve to perpetuate and reinforce this lack of understanding among professional people and the public generally.

Dr. J. V. Dunworth's statement does *not* support your contention that the Calder Hall reactors will produce power for 7 mills/kw.-hr. The "first U.K. civil nuclear power station" to which he refers will be completed in late 1960 or early 1961. The British do not consider the Calder Hall reactors to be "civil nuclear power stations." The Calder Hall reactors are owned and operated by the U.K. Atomic Energy Authority and are designed to produce plutonium for weapons with power as a by-product. The civil nuclear power stations will be owned by the Central Electricity Authority or one of the other power authorities.

This situation has been carefully explained in the United States by no less an authority than Sir Edwin Plowden, chairman of the U.K. Atomic Energy Authority.

The Calder Hall reactors can make power for any price you please by adjusting the credit for plutonium. This price must be very greatly higher than the cost of plutonium in the United States to result in 7 mill power.

Some time ago I estimated that if the Calder Hall reactors were built and operated in the United States to make only power, that this power would cost between 20 and 25 mills/kw.-hr. This estimate has been confirmed by the British.

The British hope that their civil power stations to be completed in 1960/61 and thereafter will produce power competitively with coal, at least after some operating experience has been gained. However, it must be observed that this does not mean that these reactors would be cheap in the United States. In the first place, construction costs would be substantially higher in the United States due to labor rates.

The most important factor is that the British electric industry is completely nationalized and that their fixed charges on capital for power plants are in the range of 7 to 8% *per annum*. This is about one half of the fixed charges necessary on private plants in this country. This means that plants which would produce power at 7 mills/kw.-hr. in the U. K. would produce power at about 10 mills/kw.-hr. in the United States. This is not a competitive cost in the United States for any units of this size—300,000 electric kw. Publicly financed units of this size in the United States make power for about 4 mills/kw.-hr.

Actually, with the present A.E.C.-industry program we should have in operation in the United States by the early 1960's nuclear power plants which can make power for substantially less than 10 mills/kw.-hr. Such plants, if built in Britain with their financing, should make power for no more than 6 mills/kw.-hr.

In talking about the PWR at Shippingport, it should be pointed out that it is acknowledged to be the world's first true nuclear power plant. It is designed to produce only power with no attention to plutonium production. It should be noted that the Calder Hall reactors cost *more* than the PWR and that they produce *less* power.

It is true that the power costs from the PWR will be high for the first few cores. These costs could be reduced somewhat by assigning an artificially high price for such plutonium as is inevitably produced. However, the costs are high because the first cores are highly experimental in nature and because we will continue making experimental changes in them to improve them.

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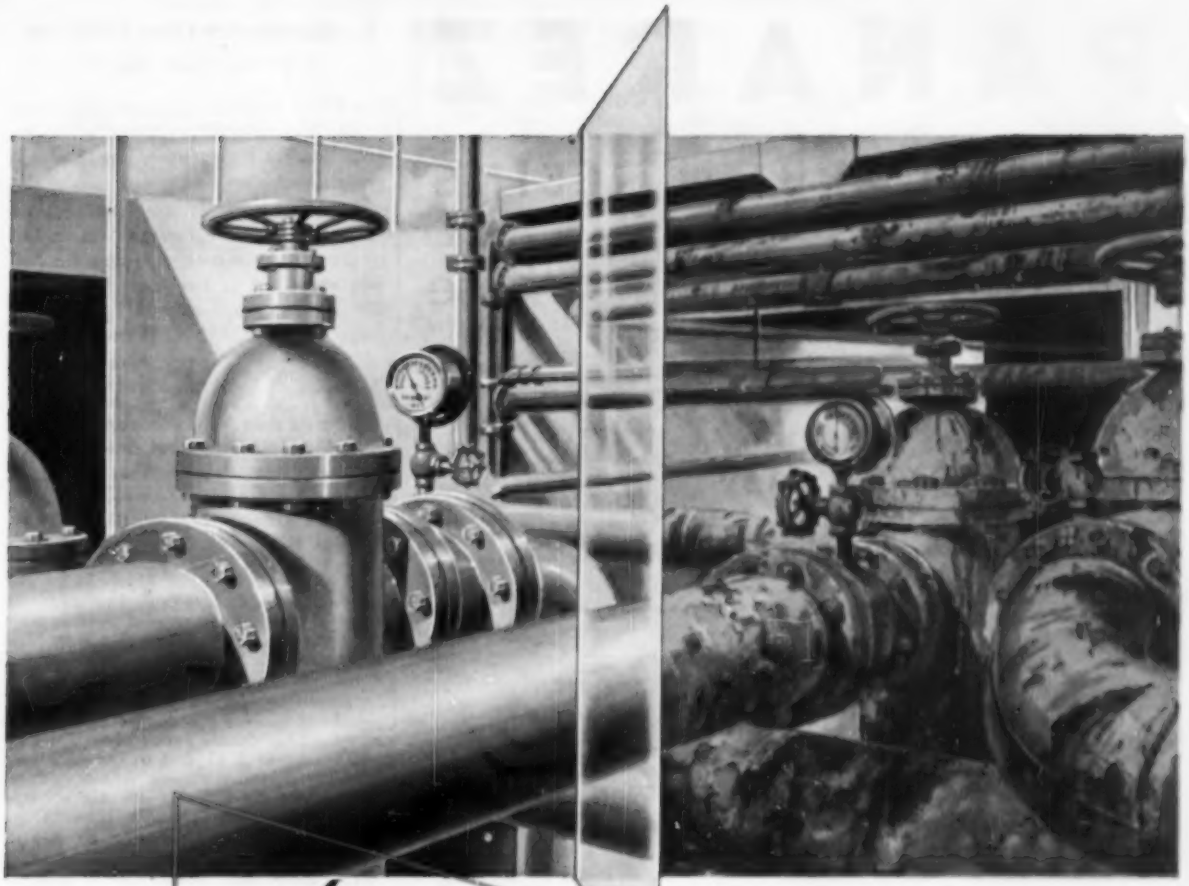

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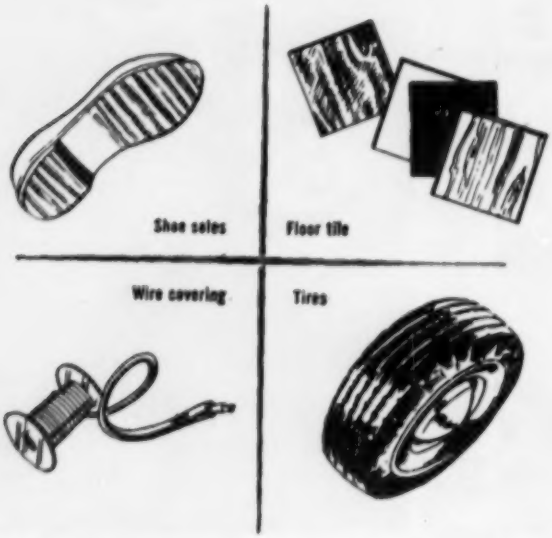

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Letters to the editor

(Continued from page 6)

The PWR is capable of producing power at far less than 52 or 39 mills/kw.-hr. even though it may never equal or approach coal costs!

One final note on your comment on insurance. The Congress was asked to provide an insurance program, a bill was voted out of the Joint Committee, and nothing further was heard of it after the Gore bill was defeated.

W. Kenneth Davis
Arlington, Virginia

Editor's note: To indicate further the confusing differences of interpretation possible from statements appearing in other segments of the press, we quote from the October 17, 1956, "Wall Street Journal":

"Sir Edwin Plowden, chairman of the Atomic Energy Authority, has said: 'It (Calder Hall) produces plutonium as well as electricity. It has not therefore been designed in the most economic way for the production of electricity.'

"Electricity costs from the plant are calculated assuming a capital cost of 8% to 9%. This figures out at about 7 mills/kw.-hr. in the U.S. But in the U.S. and elsewhere, as Sir Edwin admits, capital charges are much higher—on the average of 12% to 15% for all utility plants.

"U.S. experts figure that if all British accounting is reduced to American practices, Calder Hall would cost 10 mills to 11 mills/kw.-hr, less a 'plutonium credit' for production of this material at the plant. This plutonium credit is something of a gimmick in the figures. In British figures plutonium credits are calculated at something like 2 mills to 3 mills/kw.-hr.

"In the complex process of burning natural uranium in power stations, relatively small quantities of plutonium are produced. Plutonium is in demand currently for bomb-making, but later it can either be sold or stored against the day when Britain will be ready to graduate to more advanced reactors burning richer fuels."

Reply to Peter Soderberg on E.J.C. Employment Standards

Editor's Note: The October issue of C.E.P., page 32, carried a Letter to the Editor from Peter Soderberg, of the Research and Engineering Professional Employees Association, on E. J. C. Report on Professional Standards and Employment Conditions, pointing out that the report "fails to integrate the professional associations (sometimes called professional unions) into the scheme of advancing professionalism." His letter seemed to warrant a comment by someone thoroughly familiar with the contents and meaning of the E.J.C. report. F. E. Reese, chairman of the A.I.Ch.E.

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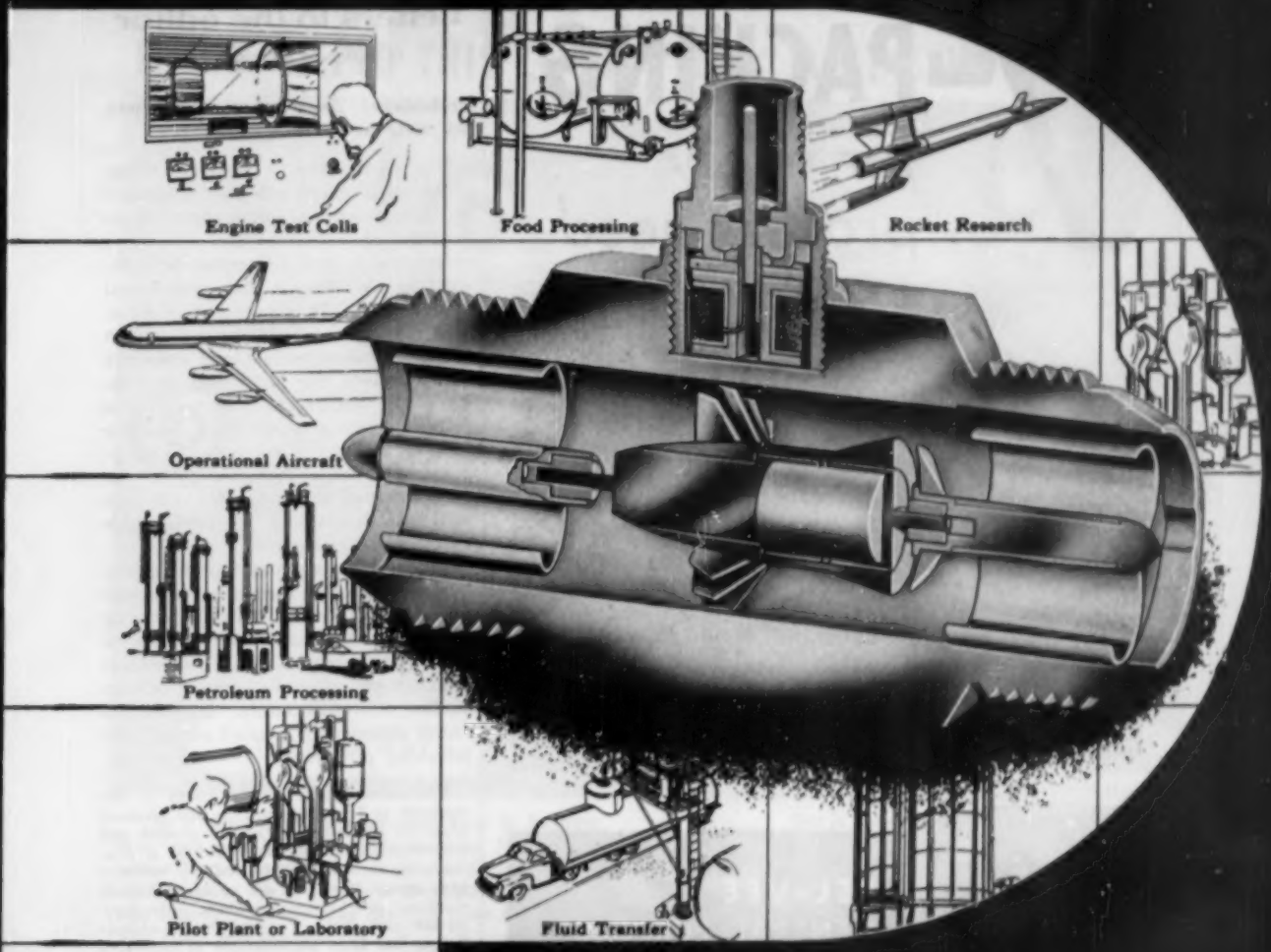

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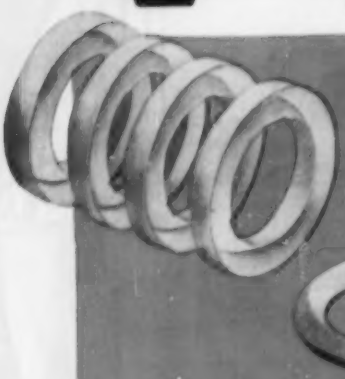

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Letters to the editor

(Continued from page 8)

Professional Development Committee, has made the following reply:

The significance of the part which professional unions will play in advancing professionalism would appear to be a matter of conjecture and opinion. I cannot find in the E.J.C. report the statement or the thought that professional unions necessarily will continue to grow. The report does highlight the conflict between professionalism and collective action where the individual is submerged in the group. The report also points out that in a recent questionnaire 72% of a group of engineers were opposed to collective bargaining for professional engineers and 66% felt that collective bargaining is incompatible with professional status.

These columns do not provide adequate space for an exhaustive treatment of all of the pros and cons of advancing professionalism via legally constituted bargaining agencies, i.e., professional unions, versus professional societies versus individual effort. However, a recent statement by Council set forth the following principle:

The enhancement of the status of the engineer is best promoted by his reliance upon his personal professional growth and accomplishment, and his status as a professional man is endangered by reliance upon group efforts to act on his behalf in reaching short-range economic objectives. At the same time, a corresponding obligation is laid upon the employer of engineers to give each professional employee his due individual recognition as a member of a profession.

Whatever path is followed, the prime emphasis must be on the individual and his personal contribution. Otherwise, we are forfeiting our right to claim membership in a profession.

F. E. Reese
Chairman, Professional Development Committee, A.I.Ch.E.
Springfield, Massachusetts

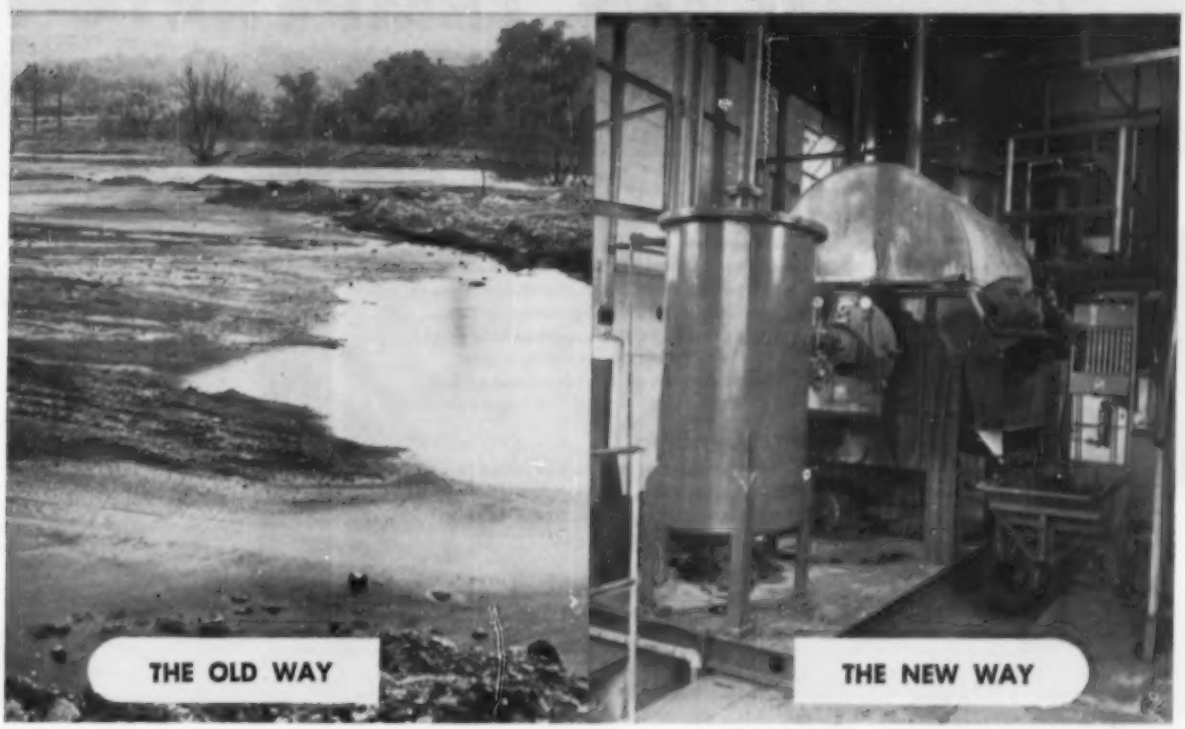
Professional Licensing

On page 20 of the July issue of *Chemical Engineering Progress*, you quote William W. Porter II on licensing.

I would like to point out that the primary purpose of registration laws is to protect the public welfare, and not to benefit engineers or the engineering profession. These laws establish certain minimum qualifications which help to guard against the potential hazards introduced into projects by incompetent and irresponsible planners and designers. I have been rather close to the registra-

(Continued on page 14)

EIMCO HELPED THIS CLIENT "FIND" A $145 HOURLY INCOME



In a molybdenum producing firm in Eastern U.S., gas was blown from a roasting furnace to water "scrubbing" tanks. First over-flow went to settling pits. Final overflow emptied into a storage lagoon. Sludge was drained from tanks and dug from pits periodically.	The Method	Gas is blown thru a wet dust collector in Eimco Precoat Filter Station. Included are a 4 X 4 Hi-Submergence Continuous Vacuum Precoat Filter, filtrate pump, 6 X 6 Precoat Mix Tank with Lightnin' Turbo Mixer and 11" D. Hy-Flow Valve. Materials of construction: Steel-PVC coated; solid PVC grids on division strips and end strips. Barometric condenser reduces air temperature and knocks out SO3 gas.
Solids recovery was less than 50%. Extremely cloudy filtrate.	Recovery	Solids recovery exceeds 95% from dry, smooth filter cake formation. High product clarity.
Operation was in the "red" due to low solids recovery. No extra values since poor product clarity hid presence of Rhenium in filtrate. Most of the profit was "seeping away" thru storage lagoon.	Result to Economy	180 lbs. moly-sulfide per hour increase over old method. Or (at 80c lb.) $145 per hour—$3500 in a 24 hour operating cycle. EXTRA VALUE. High product clarity led to the recovery and marketing of Rhenium, valued at $1700 per lb. 75 lbs. recovered to date.
Laborious, wasteful, cumbersome. Required many more hours of manual labor under difficult conditions to extract almost 50% less solids.	Operating Efficiency	Efficient, productive, sanitary. Eimco's test methods as applied to filter station design are accurate. Capacity is more than adequate; pressure drop is negligible; scraper blade operates at minimum rate; maximum operating time between reprecoating and minimum down time for reprecoating.

This profitable solution to a problem resulted from a close working alliance between the customer and Eimco's Research and Development Center at Palatine, Ill. Write Eimco today for more information of this and other installations saving process industries time, money and effort.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City
Research and Development Center—Palatine, Ill.

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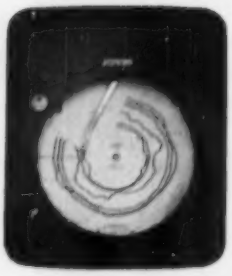
B-219

GET THE BEST SOLUTION TO ANY TEMPERATURE

with Foxboro

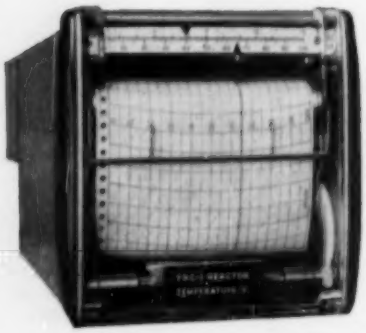


Dynalog Electronic Instruments

Complete line of indicators, recorders, and controllers employing the advanced Dynalog measuring system in which a friction-free air capacitor replaces conventional slidewire — provides continuous, stepless balancing action. Dynalog Instruments provide up to six records on a single round chart. For use with resistance or voltage type primary elements — pneumatic or electric control action.

Multi-Record Dynalog

- 6 color-coded temperature records on one round chart.
- Each record line a distinctive, non-smudging color.
- No slidewire — no batteries — no standardizing.
- Thermocouple or resistance bulb types.



Consotrol® Recording Control Station

One of the complete Consotrol line of compact panel indicators, recorders, and controllers. This advanced control station features full 4" chart and scales, six-months' ink supply, bumpless auto.-man. transfers. The M/58 Consotrol Controller, shown here integrally mounted, provides:

- All four control actions, with two reset ranges, easily adjustable to widest variations in operating conditions.
- Easy lever-setting proportional band, calibrated to 500%.
- High sensitivity and precision due to unique "floating disc" balancing action — even at widest settings of proportional band.
- Interchangeable "plug-in" components.
- Continuously variable reset resistance gives 500:1 rangeability.

PRIMARY ELEMENTS

A complete selection of primary elements for filled thermal systems, resistance bulbs, and thermocouples. Besides standard and thermocouple types, special elements and accessories are available to meet the requirements of virtually any industrial application.

Dynatherm Resistance Bulb

For use with Dynalog Electronic Instruments.

- Superior measurement performance for temperature up to 600°F.
- Fastest response due to positive metal-to-metal end contact with standard wells or sockets.
- Highest sustained accuracy. Permits use of extra-narrow scales — ideal for precise temperature difference measurements.

Roll Surface Temperature Element

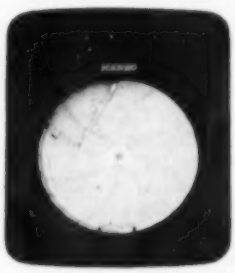
- Continuous, automatic measurement or control of roll surface temperatures up to 450°F.
- Extra-rugged construction — with a "feather" touch. Won't mark or score the roll.
- Eliminates friction, radiation, and convection errors.
- Simplest, most accurate way to measure roll surface temperatures.

PROBLEM | from −450°F to +2800°F

Instrumentation

Model 12A Temperature Pneumatic Transmitter

- Simple way to measure remote temperatures in the −100°F to +1000°F range. Operating spans of 50°, 100°, 200°, and 400°F.
- Compensated for ambient temperatures and pressures.
- Compact, easily installed. Uses regular ¼" O.D. tubing transmission lines — no troublesome conduits, no costly capillary tubing.
- Suitable for any hazardous, corrosive, or outdoor location.



Electric Proportional Action Controller

- Can be used with any Foxboro measuring system — mechanical or electrical.
- Precise, frictionless control action through electronic relay and electric valve operator.
- 3 types of proportional control action available.
- Setting knob permits easy, stepless adjustment of control band throughout range of instrument.

Whenever you have a temperature problem in the −450°F to +2800°F range, you can depend on Foxboro Instrumentation for the best solution. Foxboro's outstanding combination of truly advanced instruments and unequaled experience in applying them, has successfully solved temperature problems as widely different as helium liquefaction and jet engine testing. Foxboro offers a wide variety of primary elements, transmission devices, indicators, recorders, and controllers. Whether a single instrument or a combination is required — filled-system, electronic, or electric — you can be sure of fitting the process *exactly*. Unique Foxboro developments, such as Dynalog° Electronic Instruments, Dynatherm°° Resistance Bulbs, and the 12A Temperature Transmitter, continually maintain control standards in step with every advance of modern processing. A few of the instruments which typify Foxboro's better-engineering are shown on these pages. Chart below shows complete temperature ranges covered by Foxboro measuring systems. Write for complete details. **The Foxboro Company, 9311 Neponset Ave., Foxboro, Mass.**

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

FOXBORO

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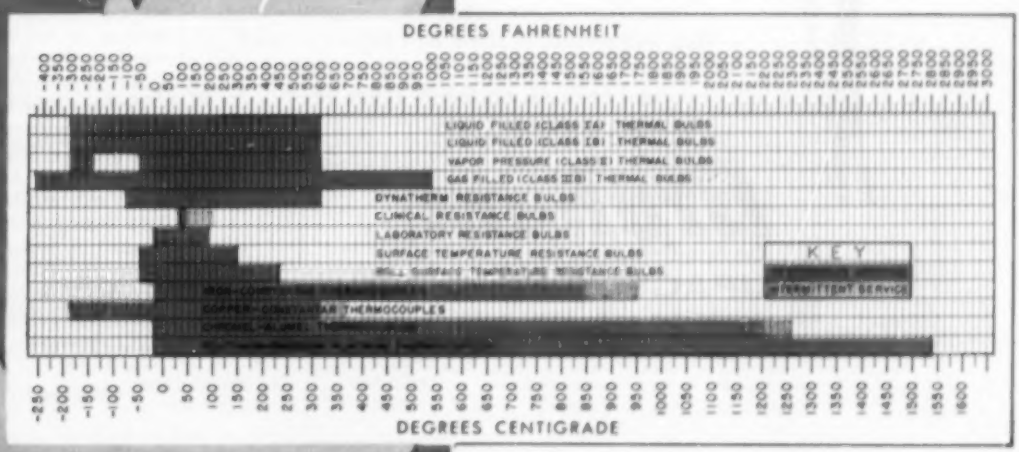
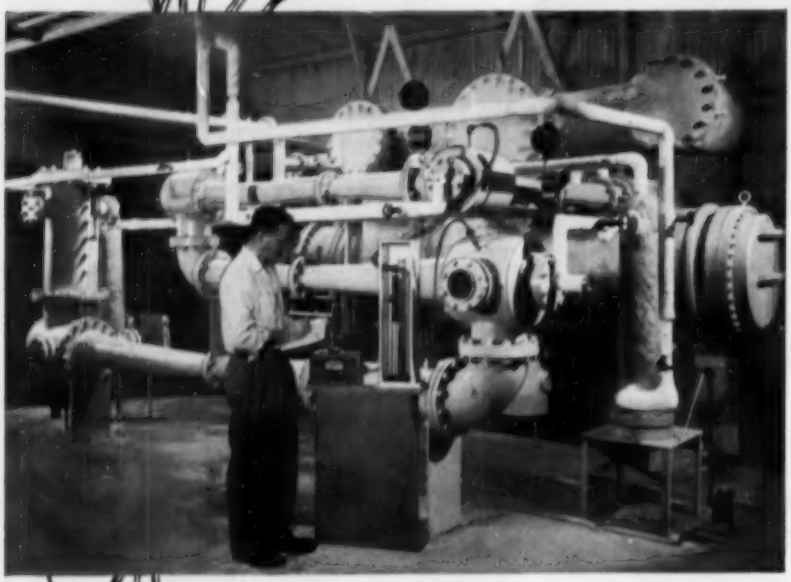
TEMPERATURE measurement and control

Locate your problem temperature in this table



*Reg. U.S. Pat. Off. **Trademark

We have gilded the lily



Here it is—six stages and 10 microns absolute

We now offer you absolute pressures approaching the ultimate — almost a perfect vacuum (pressures in the range of 1 to 100 microns).

If you can see advantages in this type of operation let us submit a proposal. Our equipment is tried and proved — and will provide you with the most economical and reliable source of extreme vacuum available today.

Graham

MANUFACTURING CO., INC.

415 LEXINGTON AVE., NEW YORK 17, N. Y.

Offices in all principal cities

Letters to the editor

(*Continued from page* 10)

tion problem and I know of no registration law that would prevent a properly qualified scientist from becoming a registered engineer, even though he lacks a degree in engineering. For those scientists who wish to practice engineering, the remedy is the same as for engineers—they must become registered. I personally know of many scientists who have done so.

A local E.C.P.D. committee on which I serve has prepared an interesting little booklet called "Professional Identification." You may be interested in the discussion on registration, pages 22 to 24. You will also be interested in the plea for membership in professional societies and the general theme of professional development.

Other booklets [of interest] published by this committee are: "General and Introductory Booklet," "Orientation and Training in Industry," and "Continued Education."

. . . We in Detroit feel that these booklets have generated a great deal of interest in professional development.

T. J. Carron

Detroit, Michigan

"If you can keep your head . . ."

I have just read your editorial "Now the Retired May Teach" and I note that one of the "ifs" was omitted. This "if" was also omitted by the Engineering Manpower Commission of the Engineers Joint Council in their release of June 12. On July 30 I wrote to W. T. Cavanaugh, Executive Secretary, calling his attention to this important "if" and I feel that you may also wish to consider it.

If a retired engineer enters this teaching service while he is on social security, he will immediately lose his social security benefits when he earns over $1,200. Even if he is teaching on a schedule equal to only 25% of a full-time teacher, he would certainly receive in excess of $1,200 per year and would automatically be penalized a large percentage of his earnings. The loss of social security benefits can be serious to a retired individual . . .

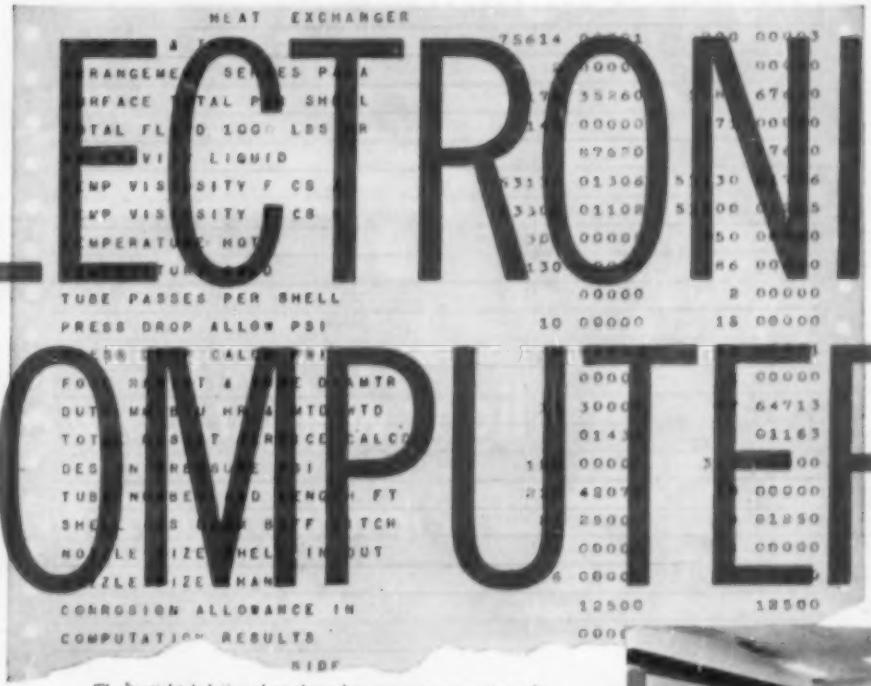
Perhaps this situation offers a good point for an attack on the present illogical ruling, which was made part of the law when our benevolent (?) government was afraid that old men would keep young men out of jobs. Social security is insurance paid for by employer and employee. It should be limited only by age or . . . disability . . . What can we do to help the situation?

H. Leslie Bullock

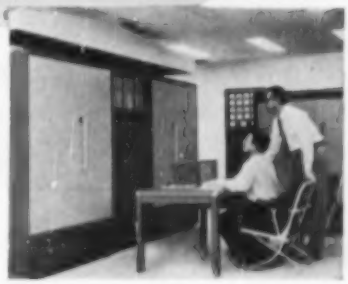
New York

(*Marginal Notes on page* 22)

More Precise Design Calculations with M. W. Kellogg's New, Super-Speed ELECTRONIC COMPUTER



The partial tabulation above shows how computer presents results. The computer itself is shown at the right.



The latest addition to The M. W. Kellogg Company's facilities for engineering heat-pressure process equipment is a new, large magnetic drum digital computer. It can execute 500 arithmetical operations per second; conservatively can solve 40 simultaneous equations in 30 minutes; and has a memory capacity of over 4000 ten-digit words.

This new computer enables M. W. Kellogg's engineering staff to undertake a far greater number of precise calculations in less time than ever before and, as a result, to determine the optimum designs for customers in minimum time. For example, complete calculations for a liquid to liquid heat exchanger, which formerly took 10 to 15 hours, now can be done in about 15 minutes.

Electronic computation is an important supplement to the productivity of Kellogg's heat transfer engineers and permits them more time for evaluating results and improving designs. We welcome the opportunity to demonstrate what these aspects of Kellogg's "built-in engineer" can contribute to your requirements.

Fabricated Products Division THE M. W. KELLOGG COMPANY 711 Third Avenue, New York 17, N. Y.

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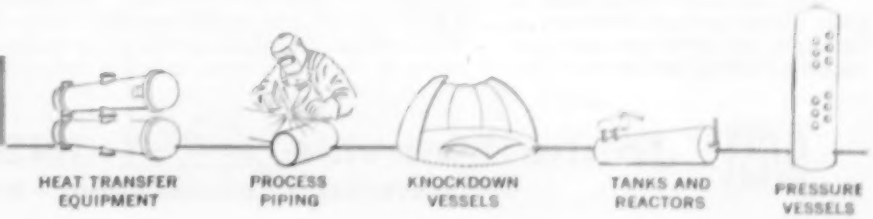
M KELLOGG W



Specify

J-M THERMOBESTOS®—the heat insulation designed for outdoor process industries

For insulating outdoor process equipment, only Johns-Manville Thermobestos adds so many physical advantages to unsurpassed insulating efficiency.

To its low thermal conductivity, there's the welcome addition of strength and rigidity. Similar in chemistry to Portland cement, Thermobestos resists crushing . . . easily withstands unusual operating abuse without appreciable damage. As for weight, you can lift even the largest piece of the material with one hand. And, of course, Thermobestos is not damaged by prolonged wetting or exposure to water vapor.

This unique combination of properties means excellent temperature control (to 1200F) and minimum maintenance cost. It is ideal for oil refineries, chemical processing plants and other plants with outdoor vessels and hot piping.

Made from hydrous calcium silicate, Thermobestos is molded to size for proper fit. Its high strength makes it particularly adaptable for time-saving shop prefabrication of fittings and bends. Thermobestos is easy to apply, and is furnished in large sections which reduce the number of joints. In half-section form it comes in sizes up to 24″ pipe diameter by 3″ thickness. Also available in 6″ x 36″ and 12″ x 36″ blocks in a full range of thicknesses. For information write to Johns-Manville, Box 14, New York 16, N.Y. In Canada, Port Credit, Ont. Ask for brochure IN-169A.

Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION

AN ADAMS *Report*

• Filtration the Answer to High Costs of Industrial and Process Water

Part 1

The continued expansion of our free economy is forcing management and design engineers to face the problem of *water*. Water is as essential to industrial development as it is to human life.

Municipal Supplies Limited

More and more we read stories in the daily papers of various cities which have had to apply restrictions on water consumption. While sprinkling bans may ruin your lawn this year, it is an omen of a possible water shortage in the future.

Natural Resources Restricted

The use of natural water resources . . . lakes and rivers . . . is being restricted by pollution. For example, the entire water of one of the major eastern rivers is reused seven times while moving one mile down stream. To make use of this water for industrial purposes involves an extensive treatment system . . . resulting in a high initial capital expenditure.

Water the Life Blood of Industry

This is not a patent cliche! It is a basic fact. Years ago water's primary importance to industry was as a means of transportation. Today water is essential to industrial survival. As with any commodity, as the supply decreases with respect to demand, the price per unit increases.

The cost of industrial and process water has risen rapidly during the past 10 years . . . will rise even further and more rapidly during the coming 10 years.

Methods of Solving Problem

More and more firms consider the problem of water shortage when planning the location of new plants. Plant sites are chosen near natural water resources. When the source is a river or lake, their planning often includes waste water disposal . . . a factor that did not exist some years ago.

River and lake water, particularly during rainy season run-offs, require water treatment of some sort. The higher the quality of the water needed by the plant, the more expensive the water treatment . . . but in the long run it pays for itself.

Filtration of the raw water with an Adams AWF Automatic Filter may eliminate the need for a pre-treatment settling basin. If water softening equipment is used, the AWF may also help reduce the cost of this equipment by the removal of solids from the water to be softened.

Filtration After Treatment

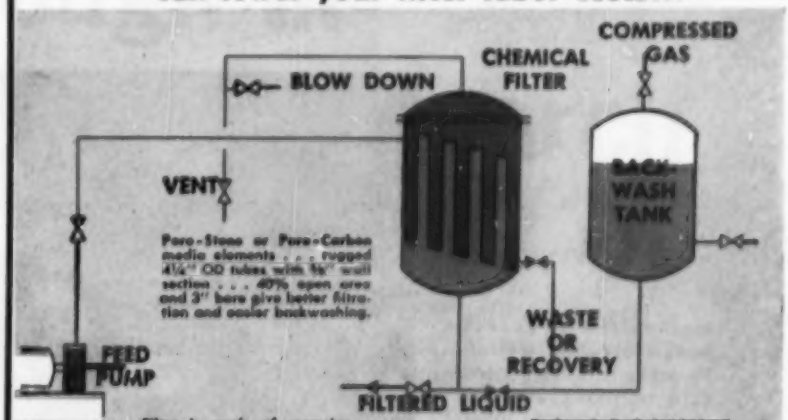
Where the polish of the industrial or process water is a critical factor, it very often pays to install a filter after the softening equipment. In this application the filter acts to remove the precipitated salts. These salts cause trouble by collecting in low spots, or reacting chemically when introduced into process solution. This phase of keeping your industrial water costs down will be covered in the next *Adams Report*. Watch for it.

New Bulletin Available

Bulletin 909, on the Adams AWF Automatic Filter is available upon request from the R. P. Adams Company, Inc., 540 East Park Drive, Buffalo 17, New York.

ADAMS BACKWASH DESIGN

can lower your filter labor costs...


COMPRESSED GAS
CHEMICAL FILTER
BLOW DOWN
VENT
BACK-WASH TANK
Pure-Stone or Pure-Carbon media elements . . . rugged 4¼" OD tubes with ⅝" wall section . . . 40% open area and 3" bore give better filtration and easier backwashing.
WASTE OR RECOVERY
FEED PUMP
FILTERED LIQUID
Filter is made of corrosion resistant alloys to meet process requirements. Note: Complete drainage from shell of filter cake after backwashing is obtained by sloping tube sheet.
Backwash Tank holds backwash liquid under head of compressed gas. Backwash liquid is forced back through filter in reverse flow at high velocities to clean filter in less than ½ minute. Note: no disassembly for cleaning.

TYPICAL BACKWASH FILTER CLEANING CYCLE

There are numerous filters which will meet the needs of your particular process. Your problem has become . . . "Which one shall I buy?"

Doubtlessly, there are other units which will produce as clear an effluent as the Adams filters. So the choice would seem to narrow down to initial investment. Here you will find Adams filters competitive in price.

What about operating and maintenance costs? That's where the Adams filter can save you money!

You clean your Adams filter by operating a few valves . . . no time consuming and often dangerous manual disassembly and cleaning necessary. Your filter is off-stream for as little as two minutes and seldom over 15. The liquid required for cleaning is only a small fraction of that needed by other filters using the reverse flow technique. And what's more, you get thorough cleaning. The Backwash liquid is easily recovered if necessary.

R. P. ADAMS CO., INC.
240 E. PARK DRIVE
BUFFALO 17, N. Y.

R. P. ADAMS COMPANY, INC. N-56
240 East Park Drive
Buffalo 17, N. Y.

Gentlemen:

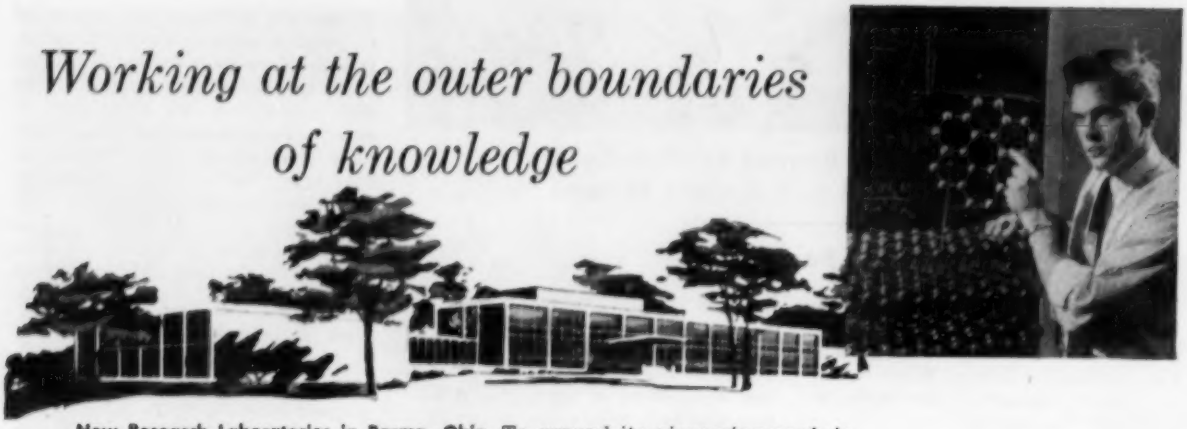
We have a problem in chemical filtration. Please send us your Bulletin 451.

Name ..... Title .....

Firm .....

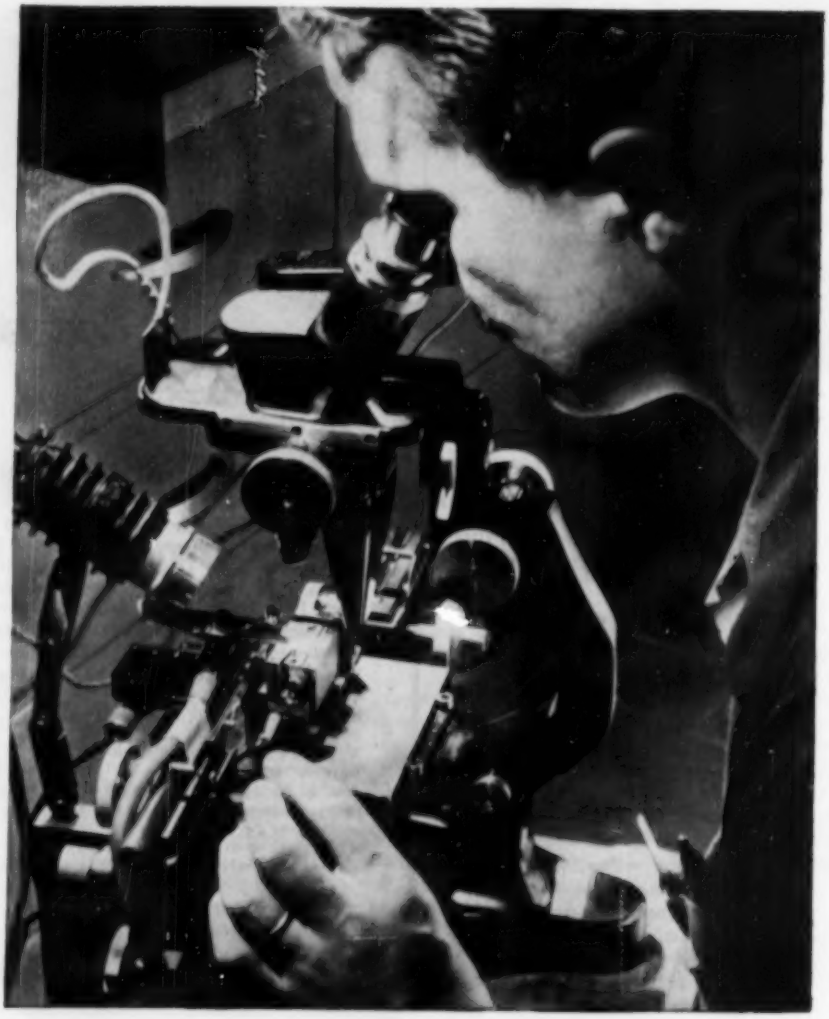
City ..... State .....

Working at the outer boundaries of knowledge



New Research Laboratories in Parma, Ohio. To expand its pioneering work in solid state and chemical physics, National Carbon Company has enlarged its staff of scientists and provided them with an ideal laboratory setup for creative work. Typical of their modern equipment is an *arc radiation furnace* used for work on high-temperature experiments. It can bring light from a carbon arc into focus on a tiny pin-point area, achieving an intensity of several hundred million foot-candles — *approaching the intensity of light near the surface of the sun.*

New



Mechanized tweezers handle graphite crystal. To make it into a proper experimental guinea pig, the fragile crystal must be painstakingly cut and mounted so that electrical flow can be measured along the unique crystalline directions of graphite. Experiments with pure crystals are important because all materials which we know as carbon and graphite are basically composed of the same graphite crystals being prepared here. Tremendous differences in electrical behavior, thermal conductivity, and other properties can be traced to variations in size and arrangement of the graphite crystals in carbon products.

Counting holes of .000004 in. diameter. Control of porosity in original material is important in producing impervious graphite process equipment. Here, liquid mercury under pressure is used to get an accurate count of pores in each size range, down as small as four-millionths of an inch.

Counting noses with Carbon-14 atoms. Relative efficiency of a "tagged" carbon anode material is determined from amount of radioactivity in CO_2 produced by electrolysis. Measuring gas ionization, the vibrating-reed electrometer detects one radioactive molecule in a billion.

break-through in carbon physics research

promises future advances in carbon and graphite products for the chemical process industries

One more barrier is down. And science strides forward in the age-old quest for deeper knowledge of carbon, one of nature's more complex puzzles.

This barrier—the inability to get large graphite crystals pure enough for experimental needs – has now been overcome by researchers of National Carbon Company. Their new annealing techniques, which remove impurities from large graphite crystals, also eliminate imperfections and weaknesses in the crystalline structure.

Several research teams at the new Parma laboratories are exploiting this break-through of science. The purified crystals are being subjected to a variety of experimental tortures—electrical, magnetic and thermal. Fundamental facts about the behavior of the single graphite crystal are being gathered and pieced together like jigsaw cutouts—building up a more complete and systematic picture. In this way, our scientists will be better able to *predict* the properties of new carbon and graphite materials.

The work on single graphite crystals is only one phase of a broad research program in carbon physics. The chemical process industries, as large users of carbon and graphite products, will share in the gains from this work of science at the outer boundaries of knowledge. Write for a new booklet titled "Research," telling more about the work at the new Parma laboratories.

Look to **NATIONAL CARBON** *for leadership in impervious graphite process equipment, activated carbon, and other industrial carbon needs*

NATIONAL CARBON COMPANY • **A Division of Union Carbide and Carbon Corporation** **30 East 42nd Street, New York 17, N.Y.**

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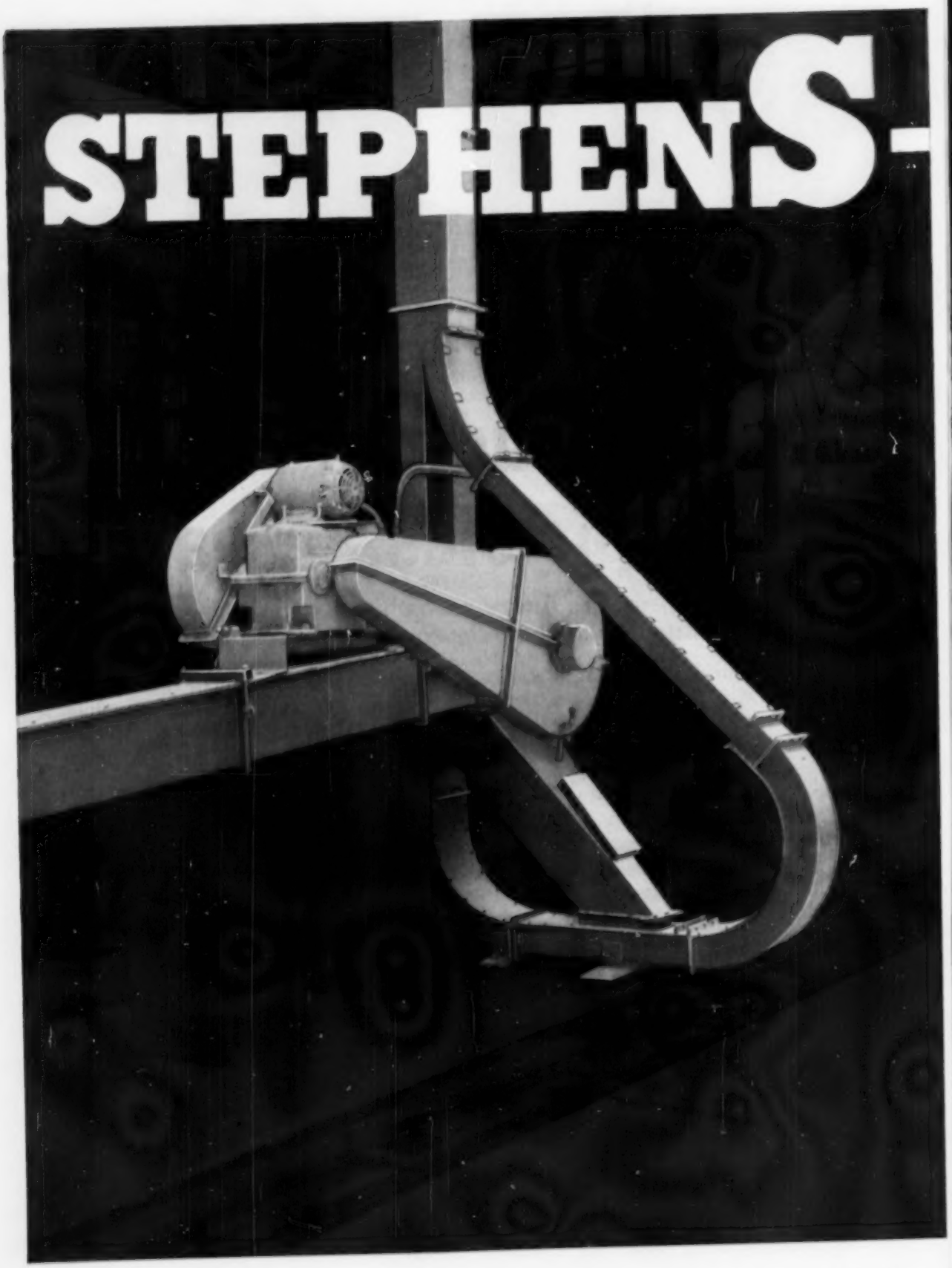
STEPHENS-



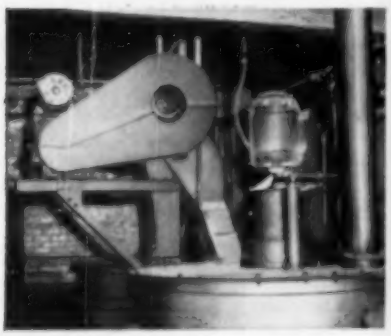
-ADAMSON

chemical product conveying systems

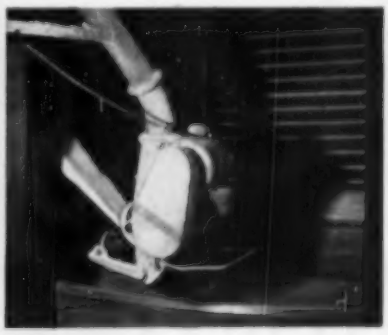
For more than half a century, S-A engineering talent and equipment have been handling the toughest conveying assignments for the vast chemical processing industry. The lessons taught by these years of experience are reflected in sound S-A equipment design and the most expedient approach to every conveying problem.

Stephens-Adamson bulk materials handling systems characteristically conform to highest standards of product protection, speed, safety in operation, and economy of movement. There is the broadest possible line of manufactured conveying products to select from in laying out any material handling system.

Whether it's design and installation of a completely new system or the revision and modernization of an old or inadequate one, S-A can help you save cost on every ton of material you move. Consult the sales engineer in your area. He can show you why it's wise to convey the S-A way.



Closeup view of REDLER head section showing a SACO speed reducer on drive. S-A builds a wide range of power transmission equipment for conveyor use.



Swiveloader insures uniform loading to maximum capacity. S-A builds five basic types of equipment for loading and unloading ships and box cars.

A big chemical processing plant employs REDLER conveyors to carry material completely enclosed and protected. Here material is discharging through pivoting chutes to mixers.

STEPHENS-ADAMSON MFG. CO.

57 RIDGEWAY AVENUE, AURORA, ILLINOIS
LOS ANGELES, CALIFORNIA
BELLEVILLE, ONTARIO

S-A manufactures a wide range of material handling products in three complete plants in the U. S. and Canada.

- Belt Conveyors
- Belt, Pan & Plate Feeders
- Ship Loading Boom Conveyors
- Stacking Conveyors
- Storage & Reclaiming Systems
- "Natural Frequency" Vibrating Conveyors
- REDLER Conveyor-Elevators
- ZIPPER Conveyor-Elevators
- Conveyor Belt Cleaners
- Headshaft Holdbacks
- Grizzlies & Screens
- Centrifugal Pilers
- Bin Gates & Tunnel Gates
- Car Pullers & Spotters
- Bucket Elevators
- Skip Hoists
- SEALMASTER Ball Bearing Units

• *Write for a bulletin on any of the above products.*

Whether you are mixing granular or pulverized, wet or dry materials, Readco's counterflow action spiral ribbon mixers will provide a thorough mix in less time and without material build-up at the bowl ends. These sturdy mixers are built for continuous or batch processing. They can be supplied for pressure of vacuum service, with or without temperature controlling jackets and in working capacities from 1 to 500 cubic feet. Readco also manufactures a complete line of double arm mixers, including laboratory and pilot plant models, vertical mixers and materials handling equipment. Modern laboratory facilities are available to assist you in determining the proper equipment to suit your needs. Write for complete details.

Marginal notes

Thermal Power from Nuclear Reactors. A. S. Thompson and O. E. Rodgers.

Reviewed by Solomon Levy, Atomic Power Equipment Department, General Electric Company, San Jose, California.

This book, following the pattern of other nuclear engineering books that preceded it, attempts to cover the more important topics in reactor design. The first three chapters are devoted to nuclear considerations, critical mass calculations, and reactor kinetics. Chapters four and five discuss shielding and reactor materials and the last three chapters deal with thermal stresses, power removal from the reactor core, and thermal power cycle efficiency.

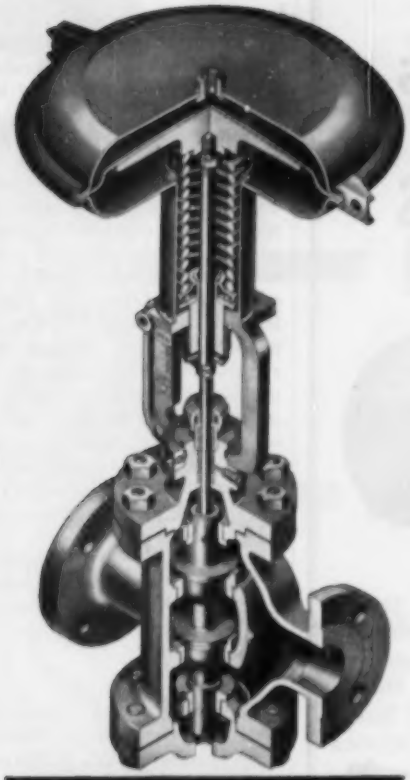
In some areas, such as shielding, reactor materials, and heat transfer, the authors' treatment is elementary; in others, their approach is not only elaborate but also novel. For instance, the application of dimensional analysis to reactor core calculations, the use of numerical methods to solve the criticality equations, the solution to the nonlinear reactor kinetics equation, the evaluation of thermal stresses in power producing elements make this work a most worthwhile reference book. However, it is this same emphasis in specific areas only, which reduces the value of the book. It causes unbalance between treatment of problems encountered in nuclear reactor design and cuts down the usefulness of the book to engineers not familiar with this new field. In those sections where the authors relate accepted engineering methods to nuclear reactor design, their effort is commendable and it is unfortunate that such sections are not larger and more numerous.

Fifth Symposium (International) on Combustion. Published for the Standing Committee on Combustion Symposia of the Combustion Institute, Reinhold Publishing Corporation, New York (1955), 802 pages, $12.00.

Reviewed by Alexander Weir, Jr., Department of Chemical and Metallurgical Engineering, University of Michigan, Ann Arbor, Michigan.

This volume contains the 101 papers presented at the Fifth Symposium on Combustion in Pittsburgh in 1954, as well as summaries of the panel discussions held on heterogeneous burning and combustion kinetics. It is an indispensable reference for research workers in the combustion field and should be studied by users of internal combustion, jet, and rocket engines.

(*Continued on page 24*)



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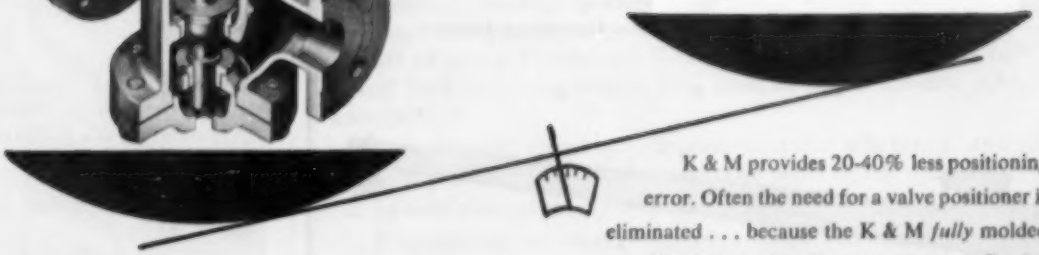

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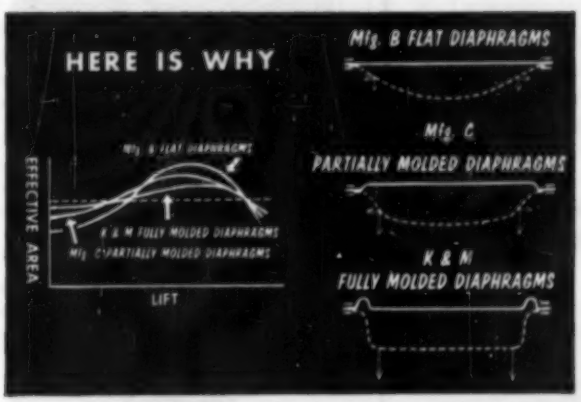

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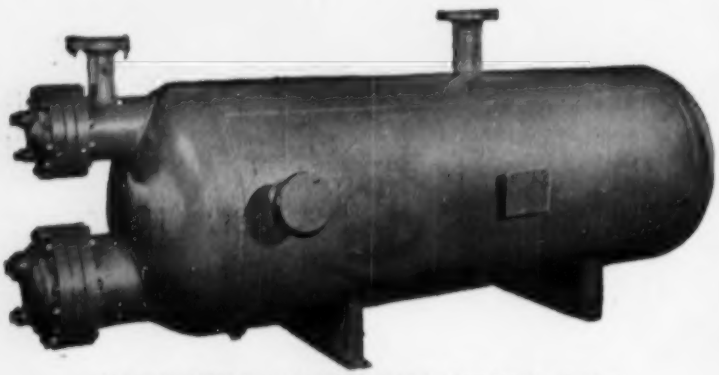

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Marginal notes

(*Continued from page 22*)

The majority of the papers are concerned with kinetics of combustion reactions. Other papers cover in part the combustion of fuel droplets, propellant burning, the combustion of solids, diffusion flames and carbon formation, combustion in engines, special techniques including shock tubes, and flame spectra and dissociation energies. In addition to these research papers, there are several excellent review papers on combustion problems in internal combustion, diesel, liquid-fuel rocket, solid-propellant rocket, turbojet and ramjet engines, as well as papers on high-temperature kinetics including collision processes, and the effect of turbulence on combustion space requirements.

One of the research papers in the combustion kinetics category discusses the effect of atomic radiation on ramjet-type engine performance.

The page size of this book is a little larger than usual, thus allowing the graphs to be easily read. It is believed that many chemical engineers will use this book.

Delayed Failure and Hydrogen Embrittlement in Steel. R. P. Frohmberg, W. J. Barnett, and A. R. Troiano. Case Institute of Technology for Wright Air Development Center. (1954), 61 pages, $1.75.

An Investigation of the Effects of Hydrogen on the Brittle Failure of High-Strength Steels. E. R. Slaughter, E. E. Fletcher, and others. Battelle Memorial Institute for Wright Air Development Center. (1956), 59 pages, $1.50.

These two reports are available to industry through the Office of Technical Services, U. S. Department of Commerce.

Systems Engineering. J. N. Warfield, Ordnance Research Laboratory, The Pennsylvania State University. (1955) 30 pages, 75 cents.

This report (PB 111801), prepared for the Navy, is designed to aid the systems engineer. It is now available to the public from the Office of Technical Services, U. S. Department of Commerce. The system survey, a preliminary step in the systems-engineering process, and the organized project plan are discussed.

(*About Our Authors on page 30*)

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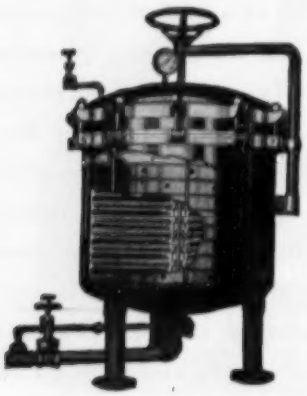

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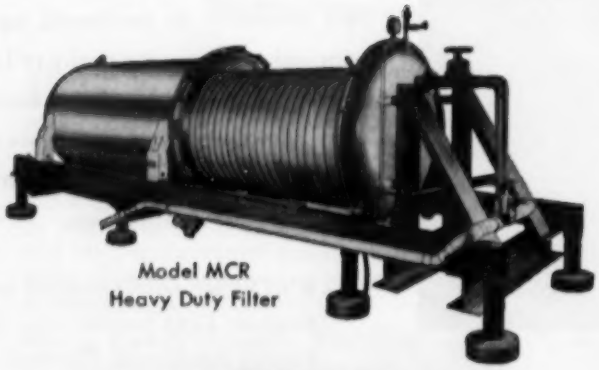

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About our authors

F. H. Hollander (*What You Should Know About Digital Computers*) is chief of SWAC Computing Facility at UCLA's Numerical Analysis Research Institute. Trained as an astronomer, Hollander served at Naval Observatory in Washington during a period when computing practices were applied to the U. S. Nautical Almanac and the Air Almanac. **C. B. Tompkins,** co-author with Mr. Hollander, is director of the Numerical Analysis facility, was principal author of the book "High Speed Computing Devices." Mr. Tompkins' humor is illustrated by the caption on one of the photos of SWAC, sent to illustrate the article, as follows: "The console unclouded by the presence of either Mr. Hollander or myself." We chose the clouds (see page 452).

Ascher Opler (*Small Computer Installation*) has had a career that has run the gamut from color theory to ion-exchange and back—from chemical structure searching to Monte-Carlo methods. "One day," he tells CEP, "a unique, unrehearsed cross-country operation took place. Following a discussion with my associates, I telephoned an inquiry to New York at 11 o'clock . . ." (Opler is on the West Coast) . . . "The answer came back at 1:30 which settled the question. What had happened was that during the 2½-hour period, the IBM 704 had been set up for a three-minute run, during which over one million computing steps were carried out."

Opler

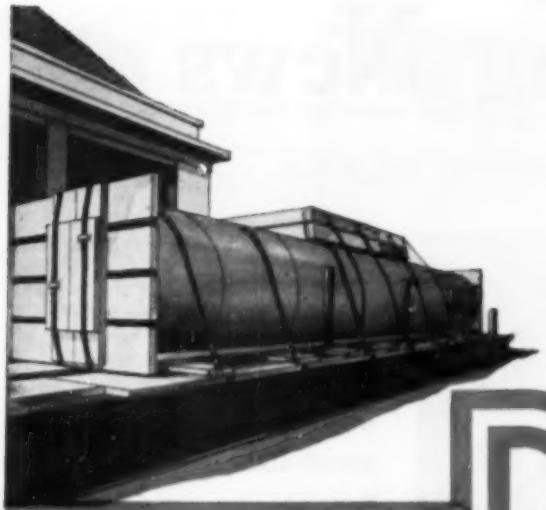
Charles R. Nelson (*Cost Estimation in the Development of a New Process*), process engineering department head at Shell Development, was selected by the Northern California Section of A.I. Ch.E. as an outstanding engineer of the Bay area for 1955. . . . **J. A. Samaniego,**

Nelson

Samaniego

his co-author, in charge of design of licensed processes with Shell, wrote: "most of the processes we license are not exclusively for achieving the primary end products, hence, my work involves evaluation to fit a client's specific application. In connection with the processes discussed in our article, for years there was considerable difference of opinion as to the relative merits of final

(*Continued on page* 34)



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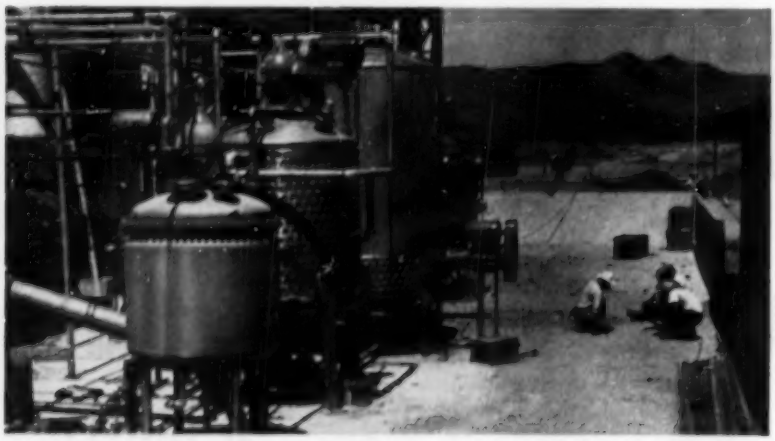

THE HEART OF FELVA'S PLANT. Pfaudler equipment lined up here (left to right) consists of a 300-gallon sulfonator, 1000-gallon neutralizer, and a 3000-gallon slurry storage tank. A side-entering mixer keeps the slurry in motion. The pipe-like equipment slanting off to the left of the sulfonator is a Pfaudler heat exchanger. And on the extreme left is a partial view of the stainless cooler. Some of this equipment must withstand the highly corrosive effects of oleum. Pfaudler glassed steel and alloy equipment prove equal to the task.

Pfaudler helps Felva set up new Mexican detergent plant

Productos Quimicos Felva—synthetic detergent manufacturer of Hermosilla—began operations in June. The event culminated a two-year program of planning and building.

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Here's what Pfaudler's project engineers did for Felva: They furnished complete installation instructions including site preparation, general layout, and piping drawings—together with some of the electrical drawings. They furnished specifications for the concrete and suggestions for Felva to use in negotiating plant construction contracts. They furnished on-the-spot aid during the erection and start-up stages. And one of Pfaudler's engineers even prepared design sketches of a water spray cooler, railroad tank car unloading platform, and other appurtenances to the plant — even though these were not the responsibility of *The Pfaudler Co.!*

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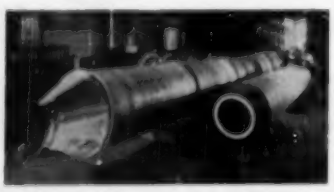

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About our authors

(*Continued from page 30*)

versions of vapor- and liquid-phase processes. It wasn't until an assessment could be based on actual plant experience that the liquid-phase process was conceded to be superior."

Theodore J. Williams (*The General Purpose Electronic Differential Analyzer*) has recently joined a newly organized section in Monsanto's Engineering Department concerned with special research in automatic control of chemical processes. With three degrees in chemical engineering, he obtained an M.S. in electrical engineering in 1956.

Williams

R. L. Mills (*Hydrogen Embrittlement of Cold-worked Metals*) describes himself as a "physical chemist by training, a low-temperature physicist by adoption and a chemical engineer by necessity." Joining Los Alamos Scientific Laboratory in 1950, he is currently exploring "a field which combines low temperature with high pressure." While

Mills

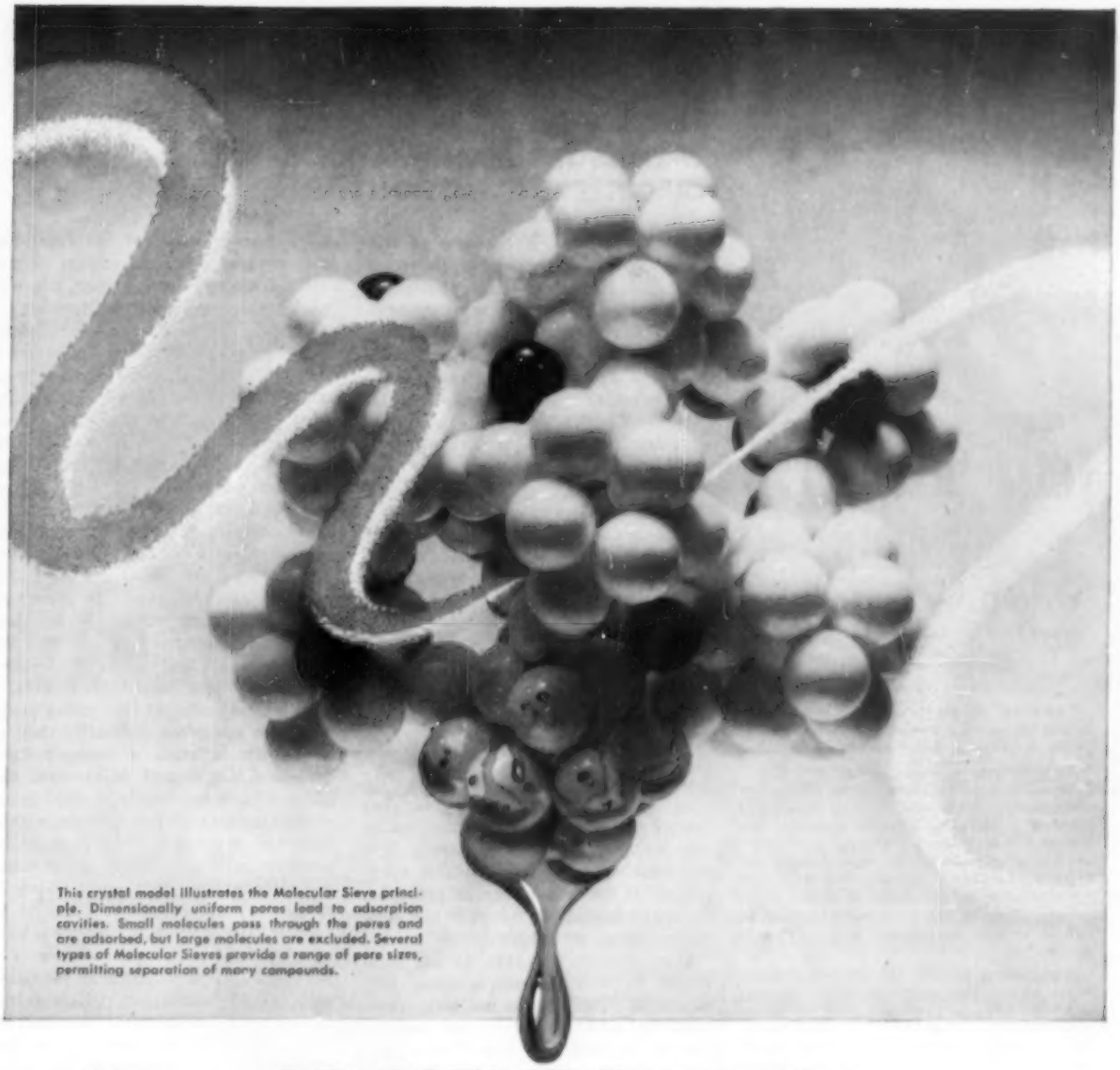
Edeskuty

determining the melting curves of the three hydrogen isotopes at pressures up to 60,000 lb./sq. in., he states he was "introduced to the hydrogen embrittlement problem." Which, we might confess, sounds to us like *the* understatement of this issue of CEP. Co-author **F. J. Edeskuty** is also at Los Alamos, is currently working on determination of P-V-T relationship of liquid He^3.

The late mail brought the following from **E. R. Johnson** (*Roasting to Remove Fluorides from Ammonium Diuranate*): "I am writing regarding Messrs. **Rutenkroger, Beers, Kreuzmann** and myself. During the time we have been with National Lead of Ohio, we have been responsible for development of a number of processing methods for recovering uranium from the various scrap materials produced by the company's uranium production operation and other AEC activities. Incidentally, because of our efforts in this field our associates have come to refer to us as "atomic junk men."

ABOUT OUR COVER

Picture credits are acknowledged as follows: *Top*, Nuclear Development Corporation, White Plains, N. Y. *Bottom*, American Air Liquide, New York, N. Y.



This crystal model illustrates the Molecular Sieve principle. Dimensionally uniform pores lead to adsorption cavities. Small molecules pass through the pores and are adsorbed, but large molecules are excluded. Several types of Molecular Sieves provide a range of pore sizes, permitting separation of many compounds.

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LINDE Molecular Sieves, a new *class* of adsorbents, offer unique performance in product purification and recovery. These crystalline zeolites provide selective separation of gas and liquid mixtures in *three* ways...difference in molecule size...or polarity...or carbon bond saturation.

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In a tremendous variety of sizes and shapes, these new porous stainless steel filters are everywhere pushing back the temperature and pressure frontiers in micronic filtration. The reason: PORO-KLEAN'S unique combination of physical properties. Its high strength, exceptional heat and corrosion resistance and adaptability to a wide variety of shapes makes it easy to apply both in industrial processing and in compact aircraft and missile hydraulic systems.

For instance take the tiny preformed shapes shown above. They are: cylinder (1), cup (2) and cup with lip (4)—all used to protect micro-finished aircraft hydraulic servo valves; disc (3) for oil filter, cylinder (5) with brazed on seat for hydraulic O-ring; disc (6) for gas turbine fuel-oil nozzle; cup (7) and (8) for diesel fuel-oil nozzle.

And, for the big jobs, you can get single or multiple PORO-KLEAN units like the 54-inch element (below, right). It's designed to filter synthetic polymer in a chemical plant with 1500 psi pressure drop and operation at 550° F.

If you have a tough filter problem, get all the details on Cuno PORO-KLEAN. You can be sure it will fit into your design. Write: The Cuno Engineering Corporation, 28-11 South Vine Street, Meriden, Connecticut. 6.2

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Noted and quoted

COMPULSORY MATHEMATICS & SCIENCE FOR COLLEGE ADMISSION?

Lewis L. Strauss, chairman of the A.E.C., terms such prerequisites a solution to both the students' problem of getting properly prepared for college, and the nation's problem of getting able students to embark upon scientific careers.

. . .Today a growing percentage of our young people apparently reject the thought of careers in science and engineering. Yet we are entered upon an era that will test to the utmost the ability of our system to cope with very great problems, and we face this challenge with a mounting deficit in an absolutely essential resource—our supply of trained manpower. College graduating classes have been furnishing only half as many scientists and engineers as we require.

Meanwhile, there are disquieting statistics to show that the Communist world is presently educating about twice as many technical people as we are. They are, of course, starting from a smaller base but the prospect of eventually finding ourselves second in available scientific skills to such forces as are today on the march in the world is not to be contemplated with equanimity.

Our problem, however, is not occasioned by what Russia is doing with education. The issue is not born of the challenge of Communism, nor the conduct of the cold war. For if there were real peace tomorrow, if the threat of nuclear war were to be forever banished . . . if these blessings were suddenly to be realized, the educational crisis would nevertheless be with us. In fact, we might then feel it more acutely, for enormous material resources presently committed to national defense would then be freed for peaceful development, and our need for scientists and engineers would become substantially greater . . . [As a further matter of] fact, we are barely graduating enough trained people each year to provide replacements, with no provision for the *growth* of our industrial civilization. Like Alice and the Red Queen, we will have to run faster and faster even to remain where we are.

There are many who must be asking: Why has this condition *suddenly* become so serious? Why was it *allowed* to happen?

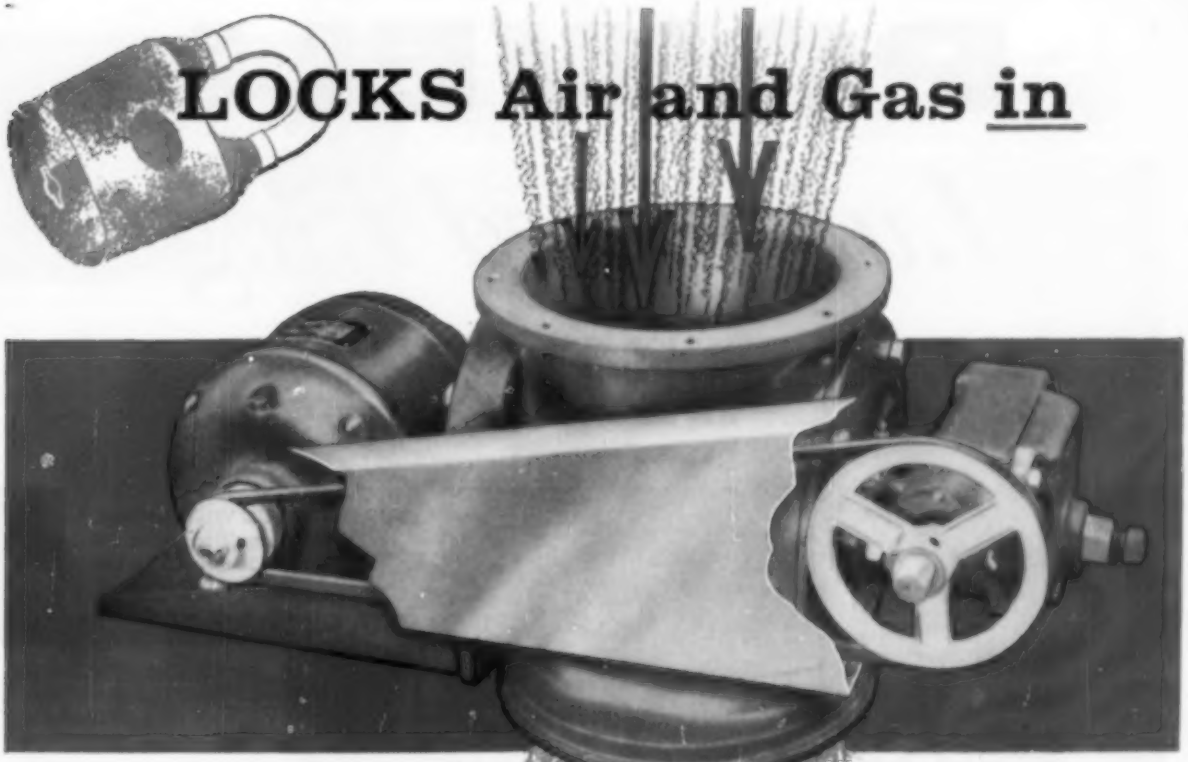
First, of course, there is the circumstance that the needs of our expanding economy and the requirements of our national security have grown, not only enormously, but very rapidly.

Also, the situation is, in part, a legacy of the economic crisis which began in Europe in the late twenties and spread to the United States in the thirties. Because of the low birth rate during those years we have had recently about one million fewer boys and girls of college age than we had in the early forties. The U. S. Office of Education estimates that it will be 1960 before we will have as many young people in the college age-group as we had back in 1945 and 1946. . . . Those events of the forties aggravated a situation which has been with us for a longer period, and that is a steady decline in science and mathematics *teaching* in our high schools. It is in the high schools that young people reach the age when ordinarily they are fired with ambition to prepare for a career. Colleges and universities cannot graduate technically trained people if students do not come to them with an objective and with adequate scholastic preparation. . . . [But] it is not simply a matter of our teen-agers losing interest in these subjects. There is the further disheartening statistic that about one-fourth of all the high schools in the United States offer their students neither physics nor chemistry. . . . [Then, too,] of our most intelligent high school students—those in the upper 20 per cent of their classes—fewer than half go on to college. And of those who *do* continue on, only about one-third remain and graduate. The others drop out . . . for various reasons. College deans of engineering tell us that perhaps first among the reasons is poor high school preparation. . . . Only recently, a Purdue University survey of 15,000 high school students provided a revealing insight into how our young people feel about careers in science. I was especially interested in the results because they dealt largely with the attitude toward *nuclear* science.

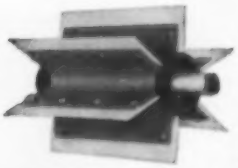
Among high school boys, that discipline was at the very bottom of the preferred careers. They would rather be storekeepers, clerks, or mechanics than enter into the exciting and challenging realm of the atom, with all its opportunities for pioneering and for serving mankind.

(*Continued on page* 40)

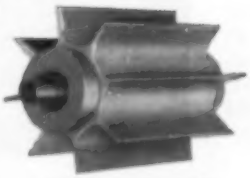
LOCKS Air and Gas in



–FEEDS Materials out!

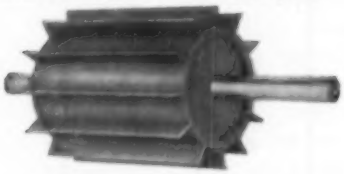


6-VANE ROTOR
with plastic, rubber, or other replaceable vanes.



12-VANE ROTOR
designed for use as a feeder, furnished with carbon steel cylinder and brass blades. Other metals available.

SOLID 8-VANE ROTOR
furnished in cast iron, bronze, stainless steel, monel, etc.



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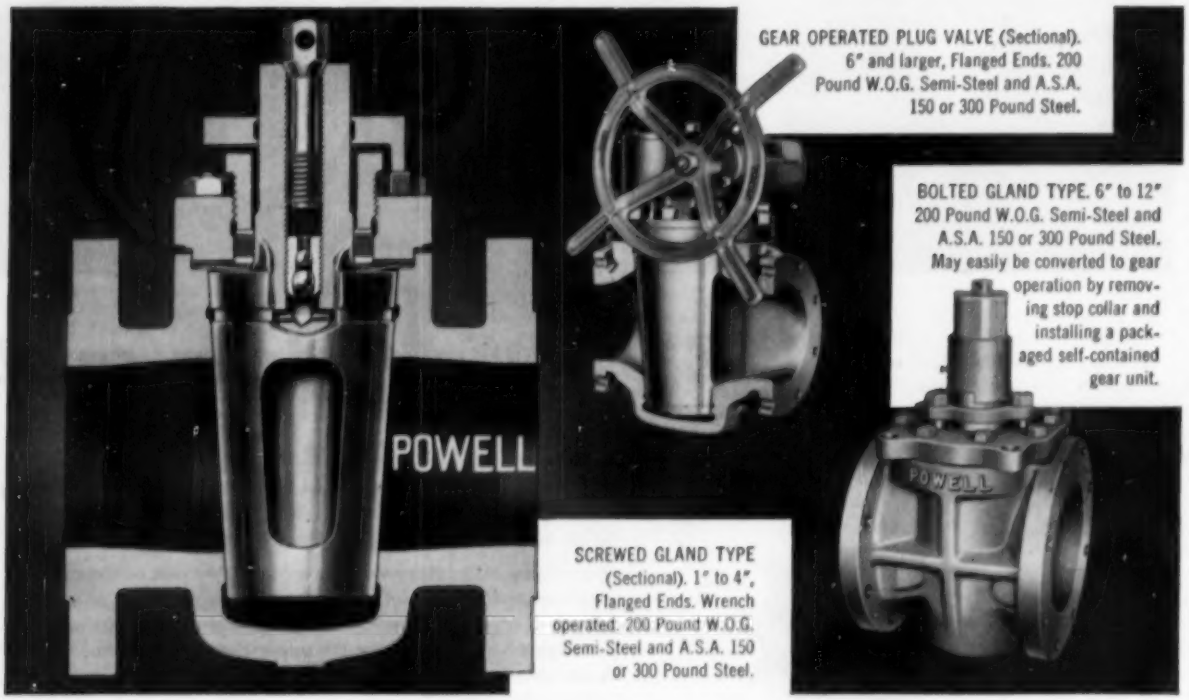

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Valve users who want one source of supply for lubricated plug as well as all types of bronze, iron, steel and corrosion-resistant valves will want full details on Powell Lubricated Plug Valves.

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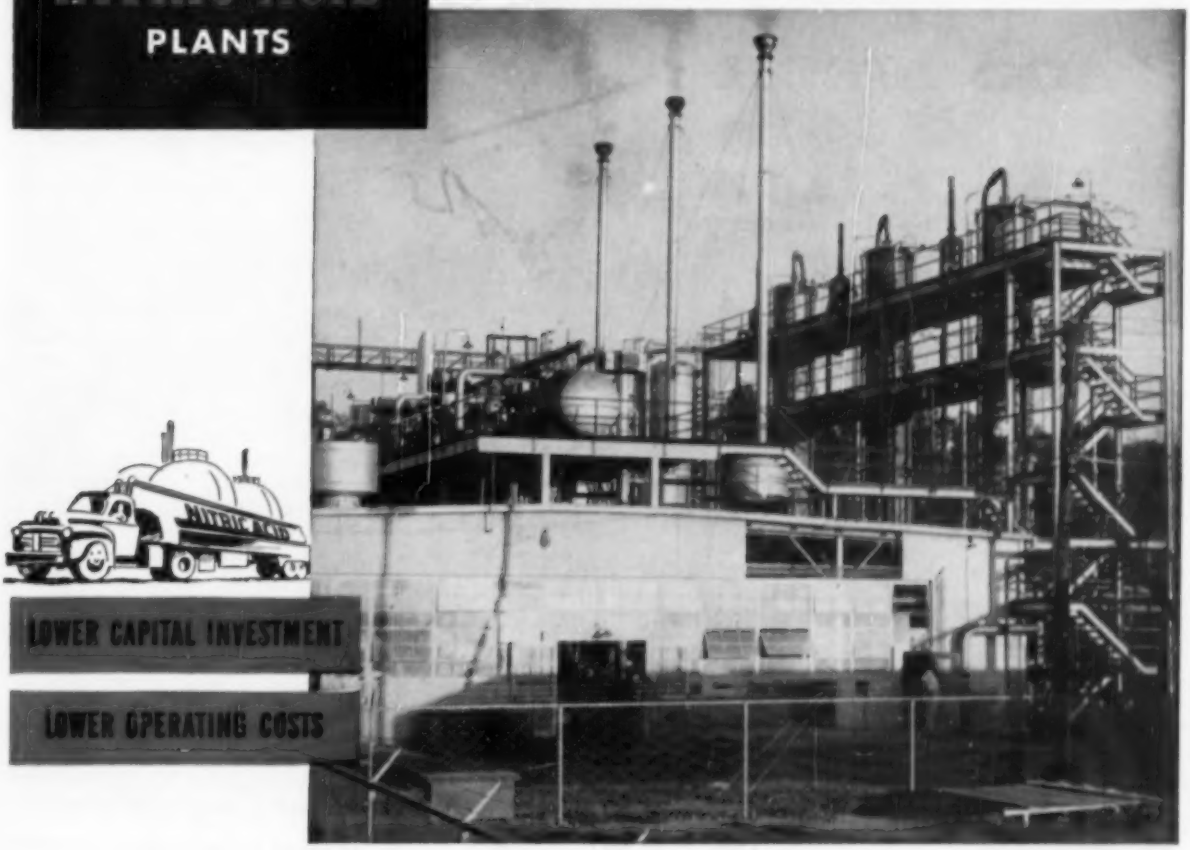

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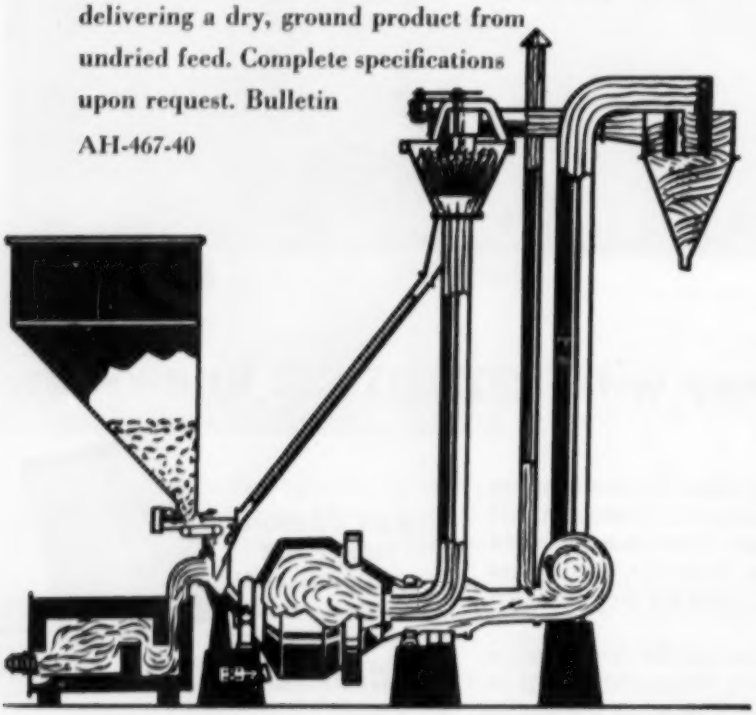

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Noted and quoted

(*Continued from page 36*)

Why did they reject science so emphatically? Some of the reasons given by as high as 27 per cent of the total number were startling, but the most alarming statistic in the survey was that 45 per cent of the students assessed their own high school training as too poor to permit them to choose careers in science. . . . The Engineering Manpower Commission of E.J.C. has estimated that "one third of our youngsters are studying mathematics under instructors not qualified to teach it." In science, there are more part-time teachers in our schools than there are full-time ones. And since there are not enough qualified teachers to go around, the alternative becomes one of using unqualified teachers or abandoning the courses. The latter alternative, sad to relate, too often becomes the solution. . . . I believe that the lack of qualified teachers, which is at the root of our difficulties, is attributable directly to the inadequate compensation offered, and to public apathy in the face of that fact.

I know that having found fault one ought to come forward with a constructive proposal whether or not it is acceptable, and I shall do so. It has seemed to me after much consideration that the cure for this condition is not difficult to prescribe. It is close at hand. The colleges themselves can correct it.

All that will be needed is for the associations such as the American Council on Education, the Association of American Colleges, the Association of American Universities, and the Association of Land Grant Colleges and Universities to meet and agree that college entrance requirements will be stiffened to include a minimum of credits in the sciences and mathematics for *all* students in whatever courses.

. . . If school boards find themselves compelled to provide science and math instruction of a certain level to ensure their local high school graduates of admission to college, they will provide that instruction. Popular pressure will compel it, as it compels adequate fire and police services. And the funds will be forthcoming at the level of local taxation to pay proper salaries to get qualified teachers.

No less an authority than Michael Faraday, the great English scientist, is quoted as having said: "If you want science, you must begin by creating science teachers."

—*Condensed from a talk delivered to The Cooper Union Convocation Dinner, New York, October 9, 1956.*

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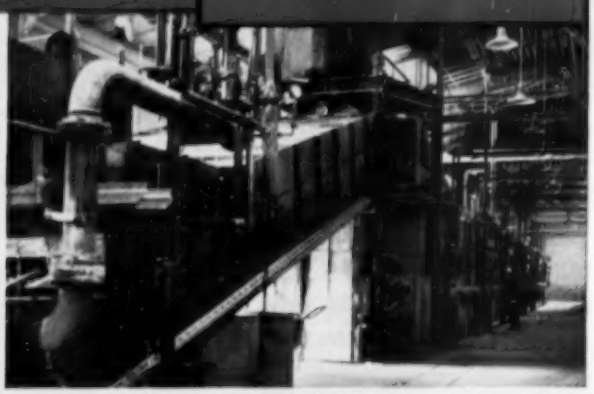

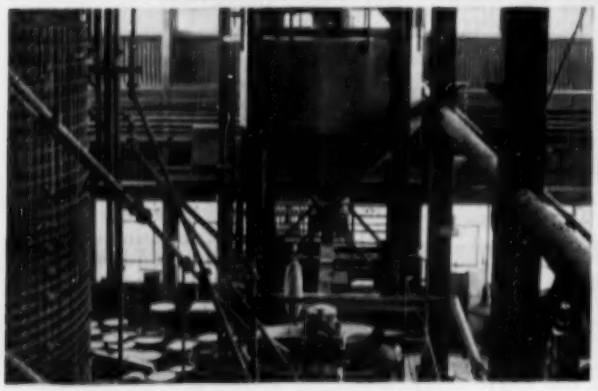

The Houdry Paulsboro, N. J., plant, built in 1940, was the first commercial plant in the world to produce synthetic cracking catalysts. In the past 16 years, facilities have been expanded to produce a general line of pelleted catalysts.

The shape of things to come in the chemical industry is just beginning to be revealed in the current big research push in solid state physics. Though of course not a new concept, solid state physics is a term new to many engineers.

The name of this science hardly reveals its real significance. One of the chemical industries' research leaders recently called it "another scientific frontier, the most challenging of all."

Solid state physics is of course the study of the inner structural nature of materials, with emphasis on the electrons of the atom, rather than the nucleus or core, which is the chief province of atomic physics. Since it is the electrons that play a key part in chemical reactions, further study in the field is expected to reveal a whole realm of new and useful knowledge.

Its practical results are expected to give a tremendous impetus to the knowledge of inorganic chemistry, of metals, and of intermetallic compounds. In long range significance this science may have as big an impetus to our economy as the petrochemical boom which got under way in the early 1920's. In 1925 the production of the petroleum chemical industry was only about 75 tons, whereas production now is in the realm of 15,000,000 tons annually and is still going up.

Another Manpower Shortage

At present, as in most of the other sciences, there is a serious manpower shortage in the field. Not too many years ago there were only a few hundred people in the country qualified in this area of science. Even today, the number is probably not over 4,000, so that there is a scramble on among large industrial companies of every type to hire at least a few experts in the field. Not only the great electronics laboratories and chemical firms, but airplane firms, metal firms, glass firms, and other businesses are getting as deeply into the field as they can.

Probably the industrial pioneer in solid state physics is the great Bell Telephone Laboratories, which already has a string of major discoveries in this and in related fields to its credit. It was at the Bell Laboratories that the transistor was discovered, a device that not only has revolutionized the electronics field but which is also undoubtedly the forerunner of other equally important devices.

New Laboratory

The most recent important event in solid-state physics is the opening of the new laboratory by the National Carbon division of Union Carbide & Carbon Corp. at Parma, Ohio, a project which cost around $6,000,000. This is probably the only major laboratory in the country more or less exclusively devoted to studies in the solid state science.

Union Carbide is of course a major factor in carbon products, in metals, and may be credited with being the most important pioneer in the petrochemical field. The company apparently now intends to make an all-out drive in this newer major science. Carbide apparently intends to take a somewhat different tack from the approach taken by Bell and by other electronic firms.

Union Carbide's concept is based on the fact that the company in its basic thinking is primarily a chemical company and even in its operations in graphite and in metals takes the chemical research viewpoint. Although the purpose of the new laboratory is to help solve problems for the National Carbon Co., beyond this is the idea that a deeper understanding of electrons and of what makes them tick will lead to a deeper understanding of chemical reactions, of catalysts, of surfactants, and of metals. So far, for example, most work in catalysts has of necessity been empirical. Solid state physics may be a means of revealing the actual mechanism of how catalysts work and thus perhaps lead to new and better tailor-made catalysts, purpose-planned to do new jobs.

Inorganics—A Place in the Sun?

The past quarter century may well be known in this country as the era of petroleum chemistry. The next quarter century may well see notable strides in metallic and in inorganic chemicals. Curiously enough, the emphasis on organic chemistry in recent years which has seen the building of huge industries based on this division of chemistry, may have stalled developments in the inorganic field, because the interest and the potential profits are in petroleum. With the exception of the silicones and phosphate chemicals, there have been few major research developments in inorganic chemistry. This situation now seems to be on the verge of being reversed.

So far the concrete accomplishments growing out of solid state physics have been a number of intermetallic compounds and compounds of relatively little known metals with minerals. A number of these already have been shown to be valuable in various phases of electronics. There are, however, hundreds of thousands of possible intermetallic compounds, just as there are of organic compounds.

Compounds that have already been made include titanium tetraboride, which may have uses in rocket motors; cerium monosulfide, which may help in producing zirconium; cadmium sulfide, which can be used in "electric eyes"; silver iodide, going into new miniature batteries; barium titanate, with an electronic memory; and columbium nitrate, which has possibilities as a conductor.

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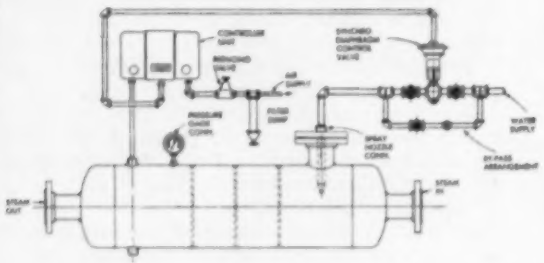

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CEP

opinion and comment

Detective Story

DISCOVERY beyond the limits of previous scientific experience seems to be the order of the day. That some of this new information will be important to the chemical process plants of tomorrow, there is no doubt. There is reason to be concerned, however, with the rate of locating and putting to work of information truly pertinent to the chemical engineering profession.

Members of all disciplines are engaged in making these fundamental discoveries, much of the work being defense-initiated. But it is the chemical engineer who bears the responsibility of being alert to recognize the presence of something of possible significance in his own field. Doing this means being literally in close contact with the project from which the development springs. Yet, recognition demands an imagination capable of soaring far beyond the processing environments of our own generation, into limits, rates, and time bases hardly known in present practice. Seeing the woods as well as the trees of tomorrow's chemical engineering can be quite a "detective" operation.

Much of the information produced in our world today is born into compartments out of which it can be freed only tediously. Even where security is not a factor in those portions of discoveries which might be of some use to the chemical engineering profession, recognition of that single portion is often difficult. The flood of discoveries each year makes it difficult to depend on the few specialists who are in contact with broad areas of discovery within their fields. If the volume of defense-sponsored pioneer development work were to be suddenly curtailed, the next few years would still be rich ones indeed for the specialists, who would then at least have time to develop for us the patterns out of the past. But the trend is not toward a slacking off. If any change in rate is indicated it is likely to be toward an even larger volume as a result of continuing international tensions.

If really prompt recognition of these new discoveries (followed by action on the part of the profession) is to be had, it must arise from the alertness of greater numbers of chemical engineers who are in positions of contact with current discovery, and whose hunches can lead them to "sound off" when they come across something interesting —even when they do not necessarily know what the ultimate applications may be.

There are several ways the observer of discovery can act in bringing about communication to the profession. One is indirect: it entails acting as an instigator to get the discoverer to write a communiqué on "certain possible chemical engineering aspects" of his findings for publication. Another is to write *about* the other fellow's findings, adding your own interpretations as to the chemical engineering significance. Or, one can write to C.E.P. about the finding and its meaning, whereupon we will endeavor to track it down and make certain that *someone* does the writing.

J.B.M.

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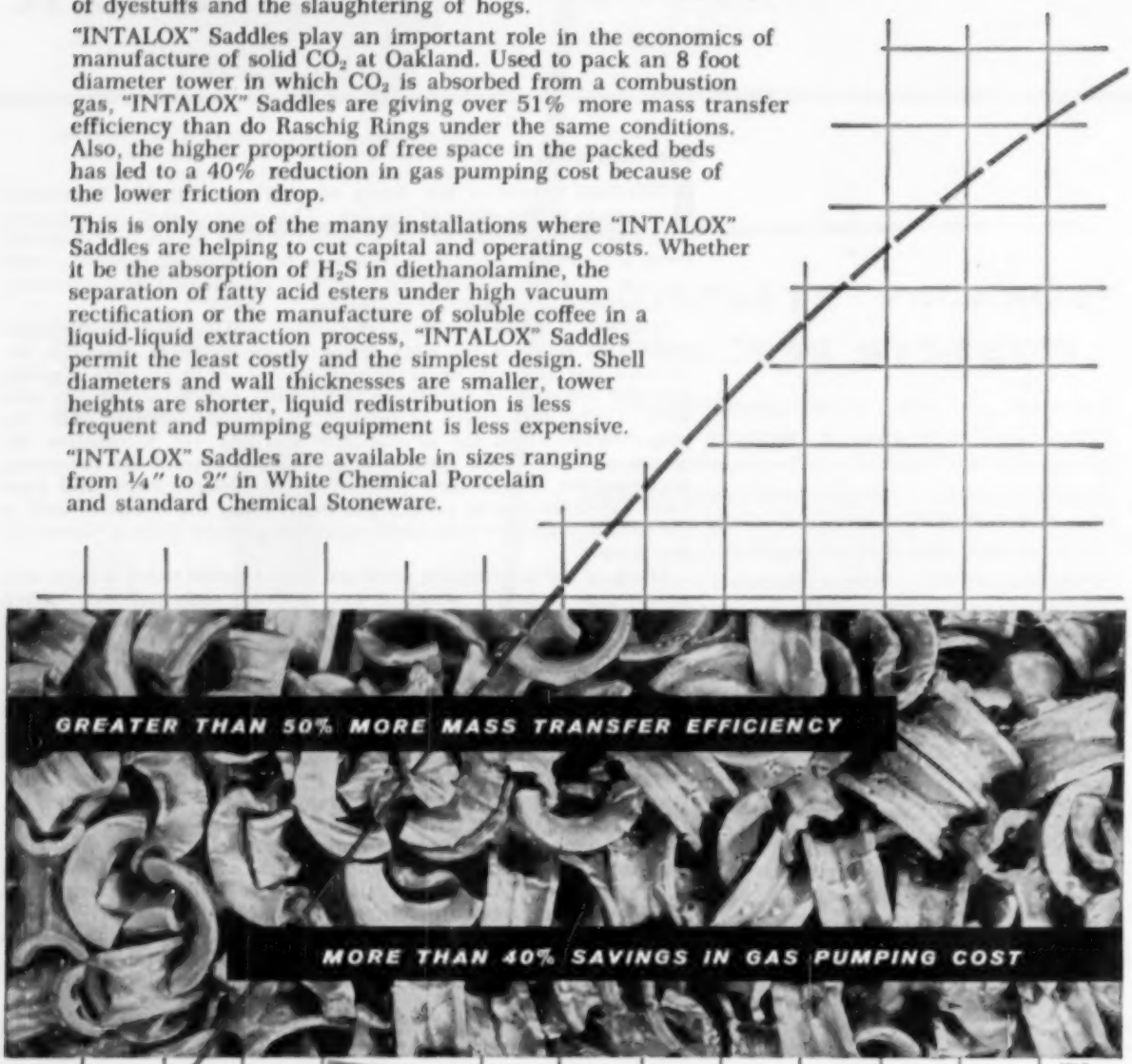
"INTALOX" Saddles play an important role in the economics of manufacture of solid CO_2 at Oakland. Used to pack an 8 foot diameter tower in which CO_2 is absorbed from a combustion gas, "INTALOX" Saddles are giving over 51% more mass transfer efficiency than do Raschig Rings under the same conditions. Also, the higher proportion of free space in the packed beds has led to a 40% reduction in gas pumping cost because of the lower friction drop.

This is only one of the many installations where "INTALOX" Saddles are helping to cut capital and operating costs. Whether it be the absorption of H_2S in diethanolamine, the separation of fatty acid esters under high vacuum rectification or the manufacture of soluble coffee in a liquid-liquid extraction process, "INTALOX" Saddles permit the least costly and the simplest design. Shell diameters and wall thicknesses are smaller, tower heights are shorter, liquid redistribution is less frequent and pumping equipment is less expensive.

"INTALOX" Saddles are available in sizes ranging from ¼" to 2" in White Chemical Porcelain and standard Chemical Stoneware.



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Process Equipment Division

U. S. STONEWARE

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There have been a number of serious mishaps in large air separation plants which have caused considerable concern among users of this process. Prevention of such mishaps is not as yet satisfactorily assured. It frequently happens that an air separation plant will operate for years with no untoward happenings and then, for no apparent reason, a vaporizer section of the column will blow up. If this section of all air separation plants were to blow up regularly, let us say weekly, the answer to the problem would be much easier to find. Each design group and user has, however, developed certain criteria of design and operation which have helped to reduce, if not to eliminate, such mishaps completely. Mr. Kerry has, we are advised, presented the thinking of many in the industry on the possible causes of column explosions and the means to circumvent them.

—*Editor*

Auxiliary vaporizer and separator in position prior to piping connections and enclosure.

safe design and operation of LOW TEMPERATURE AIR SEPARATION PLANTS

F. G. Kerry | American Air Liquide, Inc.
New York City, N. Y.

The past history of the low temperature industry, in existence now for almost sixty years, shows a fairly creditable record of safety which may be attributed primarily to the extreme caution and respect design engineers and operators have shown for low temperature fractionation equipment. There are no detailed statistics on air separation plant explosions or mishaps. This does not imply that the industry has concealed mishaps or that its members did not cooperate to reduce mishaps to a minimum. The industry could not have reached its present remarkable growth unless it had accepted safety as its number one consideration. The main purpose of this paper is to present in as orderly form as possible general data and information which could be of service to all users of production low temperature fractionation equipment.

In the early days of the oxygen industry, air plant mishaps were, as a general rule, comparatively rare, confined and not very damaging. This can be explained by the caution and respect operators showed for the oxygen unit and to the existence of many areas with uncontaminated air. The reason for the mishaps was not always known. However, the oxygen industry was, and still is, so closely allied with the production and distribution of acetylene, whose explosive properties are only too well known, that it was a simple matter to write off an explosion as acetylene entrainment. Furthermore, oxygen units of the time were small, the biggest producing only a few tons of oxygen per day; even more important was the fact that few, if any, operated continuously. Weekly or monthly shutdowns were the rule, not the exception. Impurity accumulation, therefore, never reached serious proportions.

Acetylene the Culprit?

It was not until the late thirties and during the early part of World War II, when oxygen plants were being built on a larger scale and operated on a longer continuous basis, that mishaps began to occur with greater frequency and with greater intensity. The industry believed generally that acetylene was still the main culprit, although it did rule out possible entrainment of other hydrocarbons. Atmospheric pollution due to industry and automobiles was being studied seriously, but the main blame was still pinned on the general proximity of acetylene-producing plants or acetylene cylinders. To overcome mishaps, design engineers paid greater attention to proper location of intake stacks. Studies were made of neighboring industries, direction of prevailing winds, etc. In some cases, dual stacks were placed at 180 degrees. In the latter case, the use of one or the other stack depended on the direction of the wind.

In the early 1940's, Air Liquide in Canada found that the liquid oxygen in the main vaporizer contained not only acetylene but other hydrocarbons whose exact composition could not then be determined. A series of tests was planned to determine entrainment of acetylene and other hydrocarbons. The oxygen plant in Montreal was parallel to the acetylene plant and separated by a wide roadway. It was thought, therefore, that the study would reveal the influence of wind direction on acetylene entrainment as well as the cumulative effect of acetylene in the oxygen vaporizer.

Since the oxygen plant had two separate units, it was decided to run one with its standard oil-lubricated compressor, the other and smaller oxygen unit by means of a water-lubricated compressor. This test was to determine the influence of lubricating oil on hydrocarbon accumulation. Both units, one producing 200 meters per hour of oxygen, the other 100 meters per hour, had the same type of vertical multitube reboiler with flat tube sheets (Figure 1). The tests, run over a long period of time and only partially shown in Figure 2, showed quite conclusively that, if maintained below their solubility limit, acetylene and hydrocarbons did not accumulate,

NOTICE OF PRE-PUBLICATION

Mr. Kerry's paper is scheduled for presentation at 2:00 P.M. Wednesday, December 12, at the Boston Annual Meeting of A.I.Ch.E. Mr. Kerry intends to review the paper's contents only briefly in order to progress as rapidly as possible into extensions of some of the considerations dealt with therein. Interested readers are urged to prepare comments and questions in advance of the meeting, and to plan to take part in a discussion which will follow. After the regular discussion period ends, those working directly in the low temperature separation field who wish to exchange information are invited to assemble in a special room (to be announced at the meeting) for a more detailed exploration of the subject.

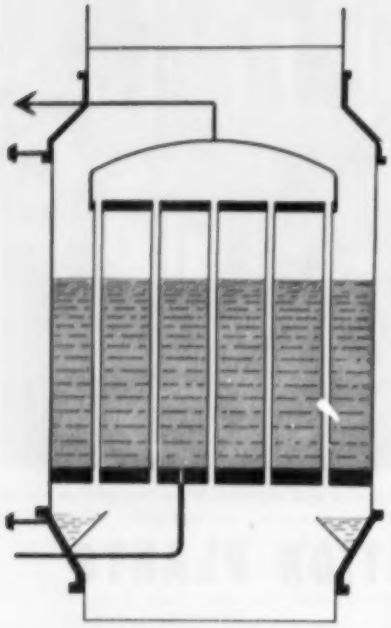


Fig. 1. Typical vertical multitube vaporizer.

but varied quantitatively and rapidly with the direction of the wind. The plant supplied by an oil-lubricated compressor showed a higher acetylene content than the one supplied with a water-lubricated compressor. This production of acetylene and hydrocarbons from thermal cracking of oil vapor had been suspected but never actually pinpointed as in this test. Obviously, greater care was needed in selection and operation of oil-lubricated compressors so that interstage and discharge temperatures would not become excessive.

Silica Gel Filters

A real contribution was the development and use of silica gel filters for the removal of acetylene from liquid oxygen. Developed in Germany and quickly put into use by all important oxygen manufacturers, these filters immediately reduced to a minimum the danger from acetylene explosions. The amount of silica gel then recommended was 10 kg./1,000 meters/hr. of air or 37 lbs./1,000 cu.ft./min. The filters were designed to remove 1 ppm of acetylene in the incoming air or 2 ppm entrained in the rich liquid at the bottom of the high pressure column. This liquid, containing 39 per cent oxygen, passes through the filters on its way to the low pressure column. With the use of silica gel filters and the sharp reduction in the number of mishaps, a few design engineers and some oxygen plant owners and operators were lulled into a false sense of security.

Fortunately, the majority of the oxygen industry did not relax its research work since the effect of a number of unknown factors remained unresolved. Attention had to be paid to the actual design of the filters themselves from the standpoint of: contamination from other impurities; permissible adsorptive capacity; regeneration temperatures and procedures; deterioration and life expectancy of the adsorbing material; and finally, design of the recipients themselves for easy inspection and replacement of adsorbing matter. Another important problem was the design of the vaporizer itself. The standard vertical multitube type was satisfactory in small sizes but, as plants and consequently vaporizers grew in size, even vaporization of liquid oxygen became a problem which manifested itself in serious accumulation of excess acetylene and hydrocarbons in the vaporizer itself.

The most important problem was contamination of air entering the oxygen plant either from thermal cracking of oil vapor from the compressor or from outside sources. The proximity of oxygen plants to metallurgical, chemical, and petrochemical processes made long pipelines for air intake almost imperative. But, with the tremendous expansion of industry, it was getting harder and harder to find an uncontaminated source of atmospheric air. Present-day atmospheric pollution around heavily industrialized areas is such that complete reliance cannot be put on normally designed rich liquid filters. Furthermore, it is not sound economic practice to overdesign these filters and switch them more frequently, since this results in a tremendous loss of refrigeration. Every time a filter is taken out of operation, the entire rich liquid in the filter is drained and wasted before deriming.

The industry had to know what contaminants were responsible for the mishaps, what physical and chemical reactions took place to produce explosive compounds and finally, what triggered off explosions. These questions are still not answered conclusively, but there is enough circumstantial evidence to narrow down the number of conditions responsible for explosions.

Chemistry of Contaminants

As mentioned previously, there are no detailed statistics on oxygen plant mishaps. Very few post-mortems have produced tangible results; this is primarily due to the complexity of the factors involved. Most mishaps were more in the nature of detonations, however small the order of magnitude, rather than combustible explosions. Under normal conditions, conclusions on the explosive combustion of hydrocarbons can be derived from:

1. Flame velocities
2. Spectroscopic analysis
3. Analysis of end products

In the case of detonations rather than explosive combustions, measurement of flame velocities or spectroscopic analysis is of no assistance. Furthermore, in the presence of excess oxygen, the chemical reaction may be complete, without any carbon deposit:

$$C_2H_2 + O_2 \rightarrow 2CO + H_2$$
$$2CO + O_2 \rightarrow 2CO_2$$
$$2H_2 + O_2 \rightarrow H_2O$$

Intensity of the explosion could be measured by studying the form of the wrecked apparatus or fragments, but this would reveal only the energy release in the chemical reaction and not necessarily the nature of the detonating compounds. Only one avenue of approach remains; namely, analysis of the end products, if any, found on the surfaces of the tubes or vessels. A wiser plan is to study the physical and chemical reactions of troublesome contaminants which could enter an oxygen plant and to design for their elimination.

For two specific reasons any straightforward hypotheses on possible chemical reactions of the contaminants would be foolhardy. In the first place, the constituents are in amounts which would normally be below their explosive limits in oxygen. Secondly, at such temperature levels no chemical reactions should take place. But, since chemical reactions and explosions do take place, the chemical field involving polymerization and partial oxidation in the presence of sensitizers should be explored carefully rather than limiting investigations to straightforward explosions with known hydrocarbons.

ACETYLENE

Acetylene has always been treated with caution and respect. All chemical engineers are familiar with its wide explosive limits, its low ignition temperature, its instability when compressed and its ability to form explosive acetylides:

	Acetylene	Methane
Explosive limits in air	2.4-81%	6-14%
Ignition temperature	330° C.	600° C.

The general atmosphere contains around 0.001 ppm of acetylene. In average industrial areas, this quantity may reach 1 ppm; in the proximity of petrochemical industries involving thermal cracking, acetylene content may well reach 15 to 30 ppm for short periods. For a long time, it was believed that detonations in oxygen plants were due to copper acetylides, Cu_2C_2. Obviously, considering the amount of copper used in the construction of oxygen plants, this was a possibility. However, mishaps have occurred in plants fabricated largely of stainless steel and aluminum and very little copper. Of course, the main vaporizer still contains a high percentage of copper. Also it is unlikely that acetylides would be formed at very low temperature levels (−180° C.) in the complete absence of moisture. Conditions for the formation of Cu_2C_2 do not exist in the vaporizer during normal operation. Cu_2C_2 could possibly be formed during deriming periods if hot moist contaminated air were blown into

the plant. However, a deriming operation is usually so brief that, if any copper acetylide were formed, it would be in trace form and its consequences could be ignored. Copper acetylides have been formed in the warm exchanger system of low temperature separation plants involving raw moist hydrocarbon feeds with very high acetylene content (1,000 ppm to 1,500 ppm) and the acetylides so formed have been entrained in the cold end. These conditions, however, are not duplicated in air separation units.

There is no doubt that acetylene gets into air plants and that the amount in excess of its solubility limit (5 ppm) is precipitated as a solid which either floats in the liquid oxygen or attaches itself to a vaporizer tube. If this were maintained for as long as three months, a serious amount of solid acetylene could accumulate. For instance, if 1 ppm of C_2H_2 be permitted to accumulate as a precipitant in the main vaporizer of a plant producing 100 tons per day of oxygen, the total weight of the precipitant would be around 1 pound. So long as the acetylene remains frozen solid, there is no danger since acetylene has remarkable stability in the solid state. But, if this solid acetylene has a considerable cross section, sublimation or liquefaction will not take place when it is heated up. Instead, there is great danger that it will polymerize or that it will break down into unstable and extremely explosive complex components. This can take place during deriming operations. It is interesting that a remarkably high percentage of explosions have taken place during restarts following plant stoppages.

OTHER HYDROCARBONS

1. Methane, because of its higher solubility limit, has little, if any, effect on the operation of oxygen plants. In 1955, Air Liquide in Canada ran a series of tests on a gaseous nitrogen plant located near several refineries. Methane content in the main vaporizer varied from a few ppm to 150 ppm and back almost as quickly as the wind changed direction. There was no cumulative effect from methane. Tests were run with new silica gel filters, with filters freshly reactivated, and with filters just about to be reactivated. These tests proved that filters have no effect on methane; fortunately, methane is very soluble in liquid oxygen and reevaporates with oxygen in the same amount as it enters the plant.

2. Hydrocarbons heavier than methane have been found in air plants but, with the exception of acetylene, they have never been analyzed quantitatively with any degree of accuracy. It also appears probable, although confirmation does not exist, that heavy hydrocarbons (particularly the unsaturates) may well undergo polymerization or partial oxidation in their passage through the compressor, especially in the presence of nitric oxide and/or nitrogen dioxide (*1*):

$$C_2H_4 + O_2 \rightarrow 2HC\text{-}HO \text{ at } 295^\circ \text{ C.} + 80 \text{ secs}$$

$$C_2H_2 + O_2 \rightarrow CHO \cdot CHO$$

Oil-lubricated reciprocating compressors with high compression ratios do introduce oil vapor into the air stream. It is likely that some cracking takes place. This has manifested itself in unusually quick filter contamination, in flash fires at compressor valves, and in higher than expected acetylene contents in the main vaporizer.

OXIDES OF NITROGEN

With increasing use of oxygen plants in ammonia production and their proximity to nitric acid plants, the presence of nitrogen oxides and their influence on hydrocarbons should not be disregarded. In the low temperature separation of coke oven gas, it has always been known that NO helps to bring about the polymerization of unsaturated hydrocarbons, especially butadiene and cyclopentadiene. The resultant product is a gummy matter which can foul up exchangers; what is worse, this complex compound has explosive properties. The analysis of this product is approximately (*2*):

C	26—60%
H_2	4— 6%
N	4— 8%
O_2	20—40%
Ash	0—50%

Although NO has been known to have a chain-breaking influence, it is likely that NO_2 has a strong catalytic effect. All experiences with oxidation of hydrocarbons indicate that such chain reactions may be retarded or speeded up by addition of small quantities of various substances. It has also been adequately established that NO and NO_2 have a catalytic or sensitizing effect on hydrocarbon oxidation and polymerization. Whether NO and NO_2 have an independent influence or whether they are involved in the same reaction has not been proved; however, the latter is more likely. Nitrogen dioxide has a favorable effect on an H_2-O_2 explosion. At 400° C. below the explosion limits of $2H_2$ and O_2 (440° C.), 200 mm of H_2 and 100 mm of O_2 exploded with the addition of 0.083 mm of NO_2 (*3*). In the presence of nitrogen oxides, acetylene reacts at very low temperatures, between 170° C. and 250° C. The result is trimerous glyoxal (up to 50 per cent of the combined acetylene). In this reaction, NO_2 is effective as a homogeneous catalyst; it is reduced to NO (*4*):

$$NO_2 \rightarrow NO + O$$

NO_2 also has an accelerating effect on methane oxidation. Oxygen atoms induce a reaction chain which could be produced as follows (*5, 6*):

$$NO + O_2 = NO_2 + O \rightarrow 47 \text{ K cal.}$$

$$NO_2 = NO + O \rightarrow 67 \text{ K cal.}$$

At 316° C. and 720 mm of mercury oxidation of ethane takes place as follows (*7*):

Mixture & Addition	Induction Time min.	Reaction Time min.
$C_2H_6 + O_2$ (dry)	30	70
+ 1% H_2O vapor	10	25
+ 1% NO_2	0	20

NO_2 is also a strong sensitizer for $C_5H_{12} + 2O_2$. By the addition of 0.004% of NO_2, the reaction time can be reduced from 75 seconds to 22 seconds (*8*). A few ppm of NO_2 could react with a few ppm of hydrocarbons in the atmosphere in the presence of sunlight to produce a complex hydrocarbon; the by-product would be ozone (*9*). The actual reaction is by photolysis:

$$NO_2 \rightarrow NO + O$$

The oxygen atom so produced reacts with an oxygen molecule:

$$O + O_2 \rightarrow O_3$$

In the absence of organic material, the nitric oxide reacts with ozone:

$$NO + O_3 \rightarrow NO_2 + O_2$$

This prevents any accumulation of ozone.

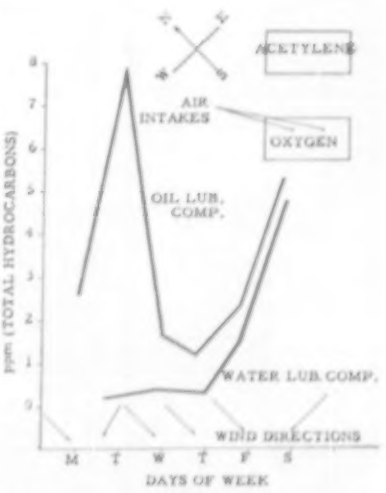


Fig. 2. Acetylene and hydrocarbon content vs. wind direction.

However, in the presence of organic substances, free radicals arising from the oxidation of organic material are believed to combine with nitric oxide to form a complex compound which could be called peroxyacyl nitrite. In this case, ozone would accumulate. Laboratory experiments carried out by the aforementioned authors have confirmed these results. It has also been determined that, in heavy petrochemical and refinery areas, the ozone concentration in the atmosphere can reach 1 ppm for short periods.

Ozone

Ozone has great affinity for silica gel and may well contaminate the filters and lower their efficiency for hydrocarbon removal. Liquid ozone is also readily soluble in liquid oxygen. But, since it has a higher boiling point than liquid oxygen, liquid ozone may well reach a dangerous concentration if the air plant is stopped and the main vaporizer is permitted to boil off indefinitely. Ozone is the most unstable of the contaminants that can enter an oxygen plant, and may well supply the key to the most important unsolved problem, namely what actually triggers off a detonation.

Safe Design Practices

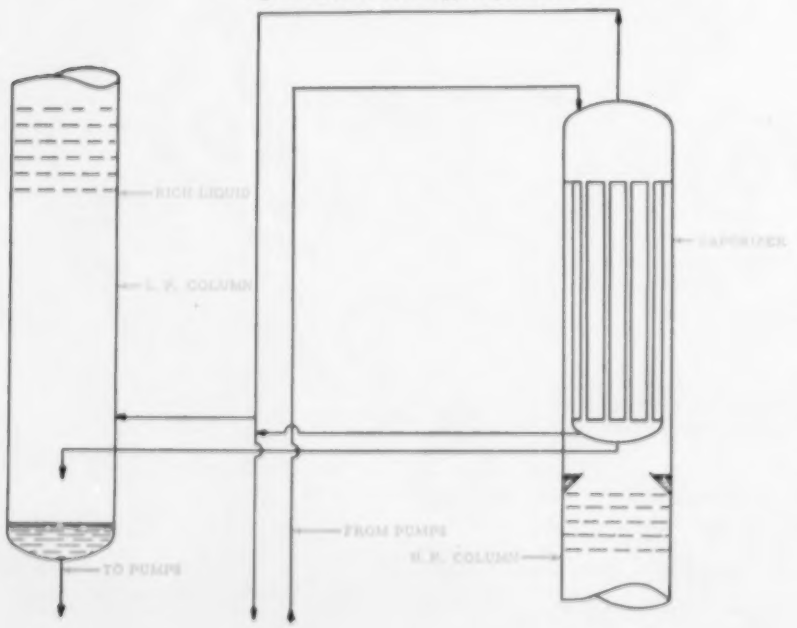
The next step is to review what the industry has done and is doing to design air separation units with a maximum of safety. In plants with standard heat exchangers, contaminants go right through and end up in the vaporizer which carries the entire production of oxygen in liquid form (Figure 3). In the vaporizer, the liquid oxygen product is in heat exchange with the slightly warmer gaseous nitrogen product which rises to the top of the high pressure column. This heat exchange results in the liquefaction of the nitrogen which is then sent to the top of the low pressure tower as a reflux; this results in the enrichment of the oxygen product by the evaporation and recondensation of the liquid in the vaporizer. By the ultimate evaporation of the liquid oxygen at very low pressure and its reentry in the front exchanger system, this design permits a very high recovery of the energy expended in air compression.

Air separation units producing gaseous products are very efficient units and can operate at low air-compressor requirements compared to units in which the oxygen product is removed as a liquid from the vaporizer. Since contaminants end up in the vaporizer, the obvious conclusion is that gaseous oxygen producing units are not as safe to operate as liquid oxygen producing units which discharged the liquid oxygen product and the entrained contaminants outside the plant. From a design standpoint this statement is correct for two reasons: (1) the vaporizer is drained continuously; (2) the oxygen vaporizes at a higher temperature level, which means that the hydrocarbons are eliminated completely. However, the same rules of safe operation must be applied in both cases.

To design a safer gaseous oxygen producing unit, Air Liquide engineers incorporated an auxiliary vaporizer which received and vaporized the liquid oxygen from the bottom of the main vaporizer. This portion of liquid contained the highest percentage of contaminants. This auxiliary vaporizer, which can handle anywhere from 30% to 100% of the total liquid oxygen product, is so designed (Figure 4) that vaporization takes place in the tubes and not in the shell as in the case of the main vaporizer. Vaporization of liquid in the tubes is more turbulent and hence slightly less efficient, but the liquid continually purges the tubes and there is, therefore, less likelihood of any accumulation of contaminants not in solution. In this manner, a higher percentage of contaminants are reevaporated with the liquid. Finally, a small amount of liquid from the auxiliary vaporizer is drained into a small vessel generally called an oxygen separator. This separator contains a liquid product with the highest concentration of contaminants.

As expected, explosions have occurred only in the auxiliary vaporizer and separator. Fortunately, the separator is nothing more than a glorified bursting disc and is expendable; the auxiliary vaporizer confines the order of magnitude of the explosion reaction because this reaction takes place in narrow tubes which offer strong resistance to a relatively small contaminant concentration per tube. As a general rule, this auxiliary vaporizer and separator are apart from the main vaporizer and fractionation equipment and are placed near the floor level close to the outer casing wall. Sometimes they are even separated from the main apparatus by a protective shield. Of course, a continuous analysis of the liquid in the separator should be made and, if contamination exceeds a safe limit, the liquid should be purged outside. In heavily contaminated areas, a continuous purge from the separator may be advisable. For a gaseous oxygen producing unit in an area of normal contamination, an auxiliary vaporizer and separator need not be considered for a productive capacity under 25 tons of oxygen/day if the main vaporizer is properly designed and if a slight continuous purge from the bottom of the main vaporizer is maintained. Nevertheless, continual analysis of the liquid product should be maintained. Above a capacity of 25 tons per day, all oxygen plants should have an auxiliary vaporizer and oxygen separator.

Fig. 3. Forced-feed, film-type vaporizer.



VAPORIZER DESIGN

In an ideal vaporizer the liquid should flow continually and smoothly as a very thin film over a very large surface. This condition would satisfy all requirements for efficient design and safety. Such lamellar flow would give:

1. Efficient heat transfer resulting in less temperature difference between liquid oxygen and gaseous nitrogen.

2. A wide distribution of contaminants either in or out of solution.

3. No dry spots at which contaminants could attach themselves.

4. A continuous purging or flushing action to prevent any concentration of contaminants.

Such an ideal vaporizer has been closely approached by Air Liquide engineers in their design of a forced-feed, film-type vaporizer. This vaporizer (Figure 5) consists of a bundle of long vertical tubes through which liquid oxygen is passed from top to bottom as a thin film spread out over the entire inner wall of the tubes. The liquid coming out from the bottom is then passed to a low pressure recirculating pump and returned to the top of the vaporizer. In this manner more liquid is passed over the inner surface of the vertical tubes than is evaporated.

This type of vaporizer has proven efficient from several design standpoints:

1. Very low temperature differential.

2. No large storage of liquid oxygen with the consequent contaminant concentration.

3. The liquid is in constant motion, providing a continuous flushing action.

4. Wide distribution of liquid helps reevaporate small concentrations of contaminants.

5. If any mishap does occur, it will be confined in a tube of fairly high strength.

Almost fourteen large-scale oxygen producing units having a capacity of 90 to 350 tons/day and using the film-type vaporizer have already gone into operation since 1949. No mishaps have occurred in any of them. This statement does not imply that this type of vaporizer is foolproof and that all other safety considerations may be disregarded. In some instances, an auxiliary vaporizer and separator have been installed as a precautionary safety measure. As indicated above, these film-type vaporizers have been installed in fairly large oxygen producing units. At present, however, an attempt is being made to redesign them in order to install them in plants having a productive capacity as low as 50 tons/day. It is felt that this would be an absolute economic and operative size limit.

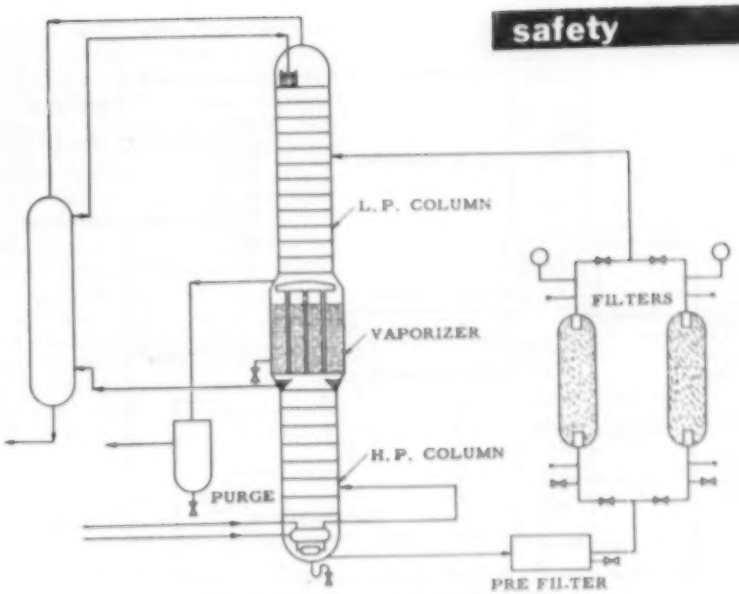


Fig. 3. Standard plant—no auxiliary vaporizer.

SILICA GEL FILTERS

To date, the most positive safety measure on hand is the silica gel filter system (Figure 3). The liquid at the bottom of the high pressure column contains all the oxygen product and about 50 mols of total oxygen plus nitrogen out of every 100 mols of incoming air. This is known as rich liquid, that is, liquid rich in oxygen. On its way to the middle of the low pressure column, the rich liquid is passed through a silica gel filter. A filter with the necessary adsorptive capacity can remove more than 96.5% of the entrained acetylene. Basically, the system is quite simple; however, close attention must be paid to the filter design details:

DESIGN DETAILS OF SILICA GEL FILTERS

1. A suitable reflux arrangement must be set up in the high pressure column to concentrate all entrained impurities in the rich liquid.

2. A mechanical prefilter may be necessary to trap out solid carbon dioxide which otherwise would be adsorbed by the main filter and would thus cut down the filter's effectiveness.

3. The main filter must be designed generously, for several reasons:

a) It should have adequate cross section to ensure free passage with minimum pressure drop and longer residual time.

b) The filter should be long enough so that the top of the filter always remains uncontaminated. This assures high removal efficiency.

c) The total amount of silica gel should exceed by a wide margin that necessary to remove the minimum amount of permissible acetylene. This assures complete removal of the dangerous hydrocarbons, such as acetylene, even though other hydrocarbons, particularly ozone, may contaminate the filter.

d) As stated previously, every time silica gel filters are switched there is a complete loss of the contained liquid. The filters should not be switched any more frequently than every four to seven days, otherwise the refrigeration efficiency of the plant will be impaired seriously.

e) As a rule, design engineers use 80 to 100 pounds of silica gel per filter per 1,000 std.cu.ft./min. of air entering the air separation unit. In industrial areas 80 lbs. per 1,000 std.cu ft./min. is a much safer design figure than the original 37 pounds used fifteen years ago. In other words, for a 100 ton/day oxygen producing unit which requires about 9,000 std.cu.ft./min. of air, each filter is filled with about 720 to 1,000 pounds of silica gel for a four- to seven-day run.

4. The mechanical design of the filter assembly should permit easy inspection and replacement of the silica gel. When filters become heavily contaminated from heavy hydrocarbons and oil vapor they should be replaced, since no amount of regeneration will restore their effectiveness. Filter contamination is indicated by a permanent black tinge. Filters should also be inspected for deterioration since powdered silica gel may get into the low pressure column and foul up the trays. What is worse, the powder may develop a high static electric charge during its high-speed passage through the piping. These difficulties may be overcome by the use of an afterfilter and use of stainless steel for all process piping.

5. The regeneration system should be designed for a regeneration temperature of 180° F. minimum. Recent tests indicate that better and safer results are obtained with a regeneration temperature of 280° F. to 350° F. Above that temperature, the silica gel may be impaired.

The importance of maintaining a high adsorption efficiency in the filter cannot be overstressed. For example, let it be assumed that (see Figure 3):

a) 1 ppm of acetylene enters the plant;
b) filter efficiency is 96.5%;
c) the K factor for acetylene is 1/15

Under these conditions, $(1 - 96.5/100) \times 100/20$ or 0.175 ppm of acetylene leaves the vaporizer with every 20 mols of oxygen. This means that 0.175×15 or 2.6 ppm of C_2H_2 remain in solution with the liquid oxygen in the vaporizer. In other words, with a high filter efficiency of 96.5%, it is

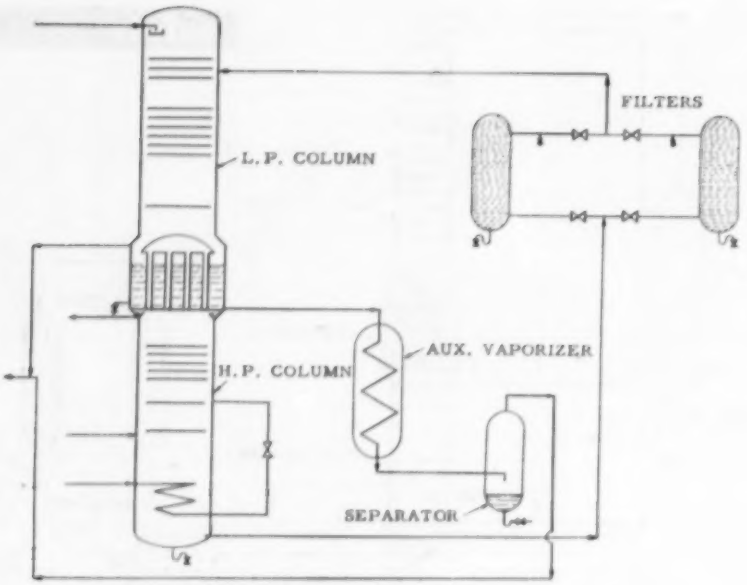


Fig. 4. Standard plant with auxiliary vaporizer.

possible to treat air with slightly less than 2 ppm of acetylene. However, if the filter efficiency drops to 93%, we obtain $(1 - 93/100) \times 100/20$ or 0.35 ppm of C_2H_2 in the gaseous oxygen product or 5.2 ppm with the liquid oxygen in the vaporizer. Since 5 ppm is the solubility limit, disregarding other considerations, we are then limited to 1 ppm of C_2H_2 in the air. It is safe practice to assume a filter efficiency of 93% and to permit only 1 ppm of C_2H_2 in the incoming air.

For an oxygen plant with an auxiliary vaporizer and separator, (Figure 4), the following calculations apply. Let it be assumed that:

a) there is 5 ppm of C_2H_2 in solution with the liquid in the separator;
b) the K factor for acetylene is 1/15;
c) 10 mols of oxygen enter the auxiliary vaporizer and 10 mols go out from the main vaporizer.

Under these conditions, 5/15 or 0.33 ppm or 3.3×10^{-4} mols of acetylene would enter and leave the separator with the 10 mols of oxygen. This also means that 0.33 ppm are in solution with the liquid oxygen in the main vaporizer and that $0.33 \times 1/15$ or 0.02 ppm or 0.2×10^{-4} mols leave the main vaporizer with the 10 mols of oxygen that are evaporated in the normal manner. In other words, $0.33 + 0.02$ or 0.35×10^{-4} mols of C_2H_2 remain with every 20 mols of oxygen product. Since this amount was carried in by 50 mols of rich liquid, then $0.35 \times 1/50$ or 0.07×10^{-4} mols of C_2H_2 remained after the filters. This means that the filter efficiency was 96.5% if 1 ppm of C_2H_2 existed in 100 mols of air. An auxiliary vaporizer can cut down the acetylene in solution in the main vaporizer to 0.33 ppm, which means a much safer operation. Then, if the acetylene content in the air goes up from 1 to 2 ppm, or if the filter efficiency drops to say 90%, the amount of acetylene in the main vaporizer will still be well below 1 ppm. Of course, the small amount of liquid in the oxygen separator becomes supersaturated with acetylene and precipitation will occur. However, in this case, the liquid in the oxygen separator is purged out.

In both of these examples, 5 ppm has been assumed as the solubility limit of acetylene in liquid oxygen. This is an experimental value and holds true under normal conditions. However, in large oxygen plants with common vertical multitube vaporizers, or in any type of vaporizer which has a large amount of stationary liquid oxygen present, it would be extremely dangerous to assume a design solubility limit of 5 ppm, especially if there is no auxiliary vaporizer. Wherever there is a large amount of liquid, the acetylene may not dissolve evenly and precipitation of solid acetylene may occur in any one section of the vaporizer even though the overall ratio of acetylene to oxygen does not exceed 5 ppm. For this specific reason, whenever standard, large bath-type main vaporizers are used, most design engineers recommend that the acetylene content in the main vaporizer be kept down to less than 2 ppm.

AIR COMPRESSORS

Selection of the right air compressor is of the utmost importance. Whenever oil-lubricated reciprocating compressors are used, there is always danger of oil mist and oil vapor entrainment. Any financial economy realized from the choice of a compressor with a high compression ratio per stage must be weighed against the dangers due to high discharge temperature: cracking of oil; carbon deposit on valves; flash fires at the discharge end; oil vapor entering the system; and what is worse, the possibility that oil vapor may be cracked and produce dangerous hydrocarbons such as acetylene. It is always advisable to keep the compression ratio per stage sufficiently low that the discharge temperature never exceeds 300° F. In fact, it is good practice to keep it around 280° F. This will keep oil and vapor entrainment to a minimum.

A mechanical filter will not remove oil vapor. It is necessary to use adsorbent-type filters. The best solution is to use an external refrigerant to drop the air temperature down to +40° F. just before the filters. Actual practice has proved that this is the best system for the protection of any low temperature unit against oil vapor entrainment arising from compression. The obvious solution is to use turboblowers wherever possible. One of the main advantages of low-pressure or medium-pressure oxygen plants is that they can be used with turboblowers which avoid the oil problem and are also economical to install. However, even with turboblowers, the question of proper cooling should not be minimized.

As pointed out previously, air contaminants such as hydrocarbons may well undergo partial oxidation or polymerization in the presence of NO, NO_2 or ozone during their passage through the compressor. This condition may well exist during the hot summer months, especially if the intercoolers are permitted to foul up.

EXPANSION MACHINES

Expansion machines should be so designed that there is no possibility of oil seepage into the expanded air. If oil does leak, the rich liquid filters will be contaminated and rendered useless for removal of entrained hydrocarbon.

CATALYTIC OXIDATION AND PREFILTERS

There are industrial areas whose atmosphere is so heavily contaminated that it would be impossible either to put in a long air intake or to rely only on the rich liquid filters. Under these conditions, there are two possible solutions; both are now being tried out for the first time.

A small Air Liquide oxygen plant in France has been in operation for well over a year in an area heavily contaminated with acetylene (10 to 30 ppm). After the compressor and before the aftercooler, the hot air passes through a tower packed with a special catalyst which oxidizes the acetylene and reduces it to less than 1 ppm. While this catalyst shows promise, it still requires study from the standpoint of manufacture, mechanical strength, and regeneration before it can be used on a large scale.

General commercial grades of a similar catalyst are being studied now in Air Liquide's research laboratory in Montreal, but it will take some time to develop a catalyst which will operate with a minimum of preheat, which will resist

oil contamination from the compressor and which will be regenerated easily. It is felt that catalytic oxidation may well prove to be the final avenue of approach to contamination removal problems.

In the meantime, several oxygen plants are now being built with large prefilters. These prefilters are large vessels filled with silica gel and are placed between the warm exchanger system and the liquefier. At this temperature level, silica gel will remove the bulk of all hydrocarbons below methane. In other words, the rich liquid filters will have only the function for which they were designed; namely, the removal of hydrocarbons in trace form. These prefilters will operate alternately; one will be in operation while the other is being regenerated.

Chemical Analysis

Prior to its entry into the low temperature unit, air should be analyzed for:

1. Carbon dioxide
2. Nitric oxide
3. Nitrogen dioxide
4. Ozone
5. Acetylene
6. Hydrocarbons (unsaturates)

Methods and procedures for chemical analysis are available from oxygen plant designers. Analyses should also be made on the liquid oxygen in the main vaporizer and in the separator (if used).

For safe limits, air should have the following maximum contaminants:

Acetylene	less than 1 ppm
$NO + NO_2$	less than 1 ppm
Ozone	less than 0.1 ppm
CO_2	less than 5 ppm
Oil vapor	zero

The liquid oxygen should have:

Acetylene	less than 2 ppm *
Hydrocarbons (other than methane)	zero

* In the main vaporizer. Less than 5 ppm in the separator.

Once a year the entire plant should be shut down and derimed completely. During this period, mechanical maintenance can be carried out. Deriming operations should be carried out according to the plant designer's instructions. Finally, the plant should be flushed with a dry gas before restarting. A dew point test should be made of the air leaving every single outlet or purge.

Conclusions

An air separation unit is no more complicated, involved, or dangerous than any chemical plant involving fractionation. With constant analysis of air, the operation of an oxygen plant should be extremely stable and easy. Unfortunately, some plant operators have consistently ignored basic operating rules, and plant designers, in their eagerness to promote the use of oxygen, have minimized the general rules to be followed for safe operation.

Plant designers contend, and rightfully so, that a plant is much safer if it operates at high air pressure and produces liquid oxygen which is then withdrawn either as a liquid or is passed through liquid oxygen pumps and converted into high pressure gas. From a design standpoint, the previous statement is true; however, since no design is foolproof, one should remember that the basic rules for safe operation still apply:

1. In a high pressure plant great care must be exercised to keep air discharge temperatures at the compressor down to eliminate oil vapor entrainment and oil vapor cracking. Therefore, low compression ratios and suitable and adequate oil filtering equipment are a must.
2. While the liquid oxygen may be withdrawn from the vaporizer, this does not mean that no contaminants exist in the vaporizer. Consequently, every rule of safe operation applicable to a gas producing unit must be followed for a liquid producing unit.
3. Every rule for checking rich liquid filters, performing constant analyses, and keeping the vaporizer at top level should be followed strictly.

SAFE OPERATING PRACTICES

- Once an oxygen plant of specific design has been installed it must be operated strictly according to the designer's recommendations.
- Compressors should be properly maintained; interstage coolers and aftercoolers should be free of fouling matter. In this manner, discharge temperatures will be kept low, around 280° F., and very little oil will be cracked or vaporized.
- If bauxite or other adsorbent-type filters are used to curtail oil vapor entrainment, they should be examined periodically. Once contaminated, they should be replaced with fresh adsorbing material since regeneration would be useless.
- Precooling the air temperature to, say, +75° F. or even +40° F. is a good operating recommendation. Such precooling not only helps to cut down oil vapor entrainment and to reduce considerably the water carried by air, but it also leads to better control by helping to stabilize the operation of the low temperature unit.
- The rich liquid filters should be switched and regenerated according to the designer's recommendations. At no time, however, should the switching exceed seven days or the regeneration temperature drop below 180° F. The entire volume of liquid in the filter should be drained completely before regeneration. The regenerating air or nitrogen should be dry and oil-free. If the silica gel begins to look brownish in appearance, it should be replaced with a fresh charge.
- The liquid in the main vaporizer should always be maintained at top level. If the plant has to be stopped for any period of time, the vaporizer may have to be drained completely. Available statistics indicate that the great majority of mishaps have taken place when the vaporizer was operating at below normal level. This implies that the explosive contaminants were given a chance to conglomerate on dry surfaces. In other words, one must consider the relationship of the total amount of contaminants to the amount of gaseous oxygen present and not the total amount of oxygen whether gas or liquid.
- In heavily contaminated areas, where there is a risk of running over the solubility limit of acetylene, 5 ppm, the liquid in the lower portion of the vaporizer should be purged continually (up to 3% of the total production). Under similar conditions, but where an auxiliary vaporizer and separator are used, the liquid in the separator (up to 3% of total production) should be purged. In the latter case, the controlling factor would be the acetylene or hydrocarbon analysis of the liquid in the separator. In both cases the purging operation must not be abrupt as it may affect the operating level of the main vaporizer.

safety

Plant designers have now had sufficient experience under their belts in the design of very large oxygen plants to be of real service to future users in the metallurgical and petrochemical industries.

Acknowledgment

The writer wishes to thank Air Liquide for its permission to publish this paper.

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What's In

Symposium Series Volume 51

(Number 17, 1955—"Heat Transfer")

Thermal Entrance-Region Heat Transfer in Liquid-Metal Systems

H. F. Poppendiek and W. B. Harrison

Several mathematical analyses for forced-convection heat transfer in the thermal entrance regions of low Prandtl modulus (liquid metal) systems are presented. An experimental set of mercury heat transfer data, obtained in a uniform-wall-temperature entrance region of a circular pipe, is presented and compared with a mathematical analysis.

A favorable comparison between the experimental mercury data and the theory brings up an interesting point.

Liquid-metal heat transfer measurements in the established flow region beyond the duct entrance have been compared with the Martinelli-Lyon momentum-transfer analogy. In general, the alkali-metals data fall very near the predicted values; whereas the heavy-metals data (mercury and lead bismuth) often fall some 40% below the theory.

One suggested explanation of this behavior is that complete wetting was not achieved at the liquid-solid interface. In the case of the mercury-copper system described in this paper one would expect good wetting because of the amalgamation that takes place at the surface.

Heat Transfer Between Immiscible Liquids

S. S. Grover and J. G. Knudsen

Rates of heat transfer were determined between a petroleum solvent and water flowing cocurrently in a horizontal circular pipe at total flow rates ranging from 2,500 to 15,000 lb./hr. and at water-to-solvent ratios from 0.2 to 3.8 by volume. Three methods of solvent injection were employed to determine the effect of mixing. In the region of the pipe where the liquids were well mixed, the rate of heat transfer in British thermal units per hour per degree Fahrenheit per cubic foot is proportional to the total flow rate to the 1.5 to 1.7 power, and for the whole pipe, which also includes a region where the liquids have separated, the rate of heat transfer is proportional to the total flow rate to 1.3 to 1.4 power except at high total flow rates. These exponents appear to be independent of the method of injection of the solvent. Results show that higher rates of heat transfer are obtained by direct contact rather than with liquids flowing cocurrently in a double-tube heat exchanger. A dimensionless correlation is proposed in which the Nusselt number, UA/kL, is proportional to the Reynolds number, DG_s/μ_w, to the 1.10 power, the effect of the Prandtl number being neglected.

Convective Heat Transfer from a Gas Stream at High Temperature to a Circular Cylinder Normal to the Flow

S. W. Churchill and J. C. Brier

The over-all rate and the angular variation of the rate of convective heat transfer from an unconfined gas stream at high temperature to a circular cylinder normal to the flow were measured on a nitrogen gas stream at 1 atm. pressure, a series of flow rates corresponding to a range of DG/μ_b from 300 to 2,300, and a series of temperatures from 580 to 1,800° F. The outer surface of the cylindrical tube was maintained at approximately 100° F. by internal cooling-water circulation.

The data for local heat transfer rates were correlated in terms of the same dimensionless groups, but the exponent for DG/μ_b varied with the angular position on the cylinder. A general graphical correlation was obtained as a function of the angular position.

From this experimental investigation of convective heat transfer from a nitrogen stream at high temperature to a cold surface, several conclusions can be drawn. Existing correlations based upon small temperature differences do not adequately represent the data for larger temperature differences. Furthermore, correlation of the data for wide temperature differences in terms of average physical properties or with physical properties evaluated at a single reference temperature does not appear feasible.

By use of the ratio of the bulk-gas temperature to the surface temperature as a parameter, satisfactory representation of the data for both over-all and local heat transfer rates was found possible. The influence of the Reynolds modulus upon the local rate varies with angle and a graphical correlation was found most convenient. Theoretical considerations indicate that the correlations are valid only for fluids for which the variation of physical properties with temperature is similar to that for nitrogen.

Heat Transfer to Viscous Materials in Jacketed Agitated Kettles

V. W. Uhl

This study extends available information for heat transfer in jacketed agitated kettles to very viscous liquids. The agitators tested were a paddle, for which considerable data are already available, and a flat-bladed turbine and anchor, for which data are scant; the liquids used were heavy bodied linseed oil and cylinder oil. The kettle was 2 ft. diam. with capacity of 50 gal. Batch tests for heating and cooling were made. Agitator speeds ranged from 50 to 250 rev./min. Power data were obtained to define the systems completely and to allow correction to sensible heat change for the mechanical energy degraded to heat.

A summary of previous work is presented. The heat transfer correlation presented. The heat transfer correlation for the three agitators studied are plotted with correlations for previous works recalculated to the basis used in this paper. In addition, it is shown that for a given rate of heat transfer all the agitators studied require about the same power input.

Nonisothermal Flow and Heat Transfer Inside Vertical Tubes

R. L. Pigford

Heat transfer to a fluid flowing in laminar motion through a vertical tube is considered mathematically, allowance being made for the effect of temperature on viscosity and density. Variation in these physical properties distorts the parabolic velocity distribution, which is realized only in isothermal flow, and affects the heat transfer rate. These effects are calculated quantitatively in terms of the ratio of viscosities at the average core fluid and wall temperatures and the Grashof natural-convection modulus. The calculated coefficients are found to agree approximately with experimental data.

Errata—October C.E.P.

In the "Round Table on Economic Evaluation," Chairman H. E. Wessel's company affiliation is listed as Monsanto. Mr. Wessel has newly rejoined Monsanto as manager of marketing research in the general development department, but at the time the Round Table was recorded (Los Angeles, February, 1956) his remarks referred to his then position with International Minerals & Chemical Corporation.

In Table 2, Case C, article "Interest Rate of Return for Capital Expenditure Evaluation" (page 405), a typographical error occurs in the column *Total Costs*. The numbers appearing beside the fourth and fifth years should be 50 and 40 instead of 40 and 30 respectively. These errors are not carried into totals in either direction and therefore do not affect any results presented.

A SHORT COMPUTER GLOSSARY

Accumulator: (Digital) (1) a unit in a computer where numbers are totaled or (2) a register in the arithmetic unit of a computer where the result of arithmetical or logical operations is first produced.

Analog Computer: A computer which calculates by using physical analogs of the variables. Usually a one-to-one correspondence exists between each numerical variable occurring in the problem and a varying physical measurement in the analog computer.

Capacity: (Digital). The number of digits or characters which may regularly be processed in a computer.

Code: A system of symbols for representing information in a computer and the rules for associating them.

Command: A pulse, signal, or set of signals initiating one step in the performance of a computer.

Differential Analyzer: An analog computer designed particularly for solving or analyzing many types of differential equations.

Differentiator: (Analog). A device whose output signal is proportional to the derivative of an input signal.

Digital Computer: A computer which calculates using numbers expressed in digits and yesses and noes, expressed usually in 1's and 0's, to represent all the variables that occur in a problem.

Feedback: The returning of a fraction of the output of a machine, system, or process to the input, to which the fraction is added or subtracted.

Input: Information transferred from secondary or external storage into the internal storage of the computer.

Integrator: (Analog). A device whose varying output is proportional to the integral of a varying input magnitude.

Magnetic Tape: Tape made of paper, metal or plastic, coated or impregnated with magnetic material, on which polarized spots representing information may be stored.

Memory (external): (Digital). Materials separate from the computer itself but holding information stored in language acceptable to the machine as, for example, recorded magnetic tape or punch cards.

Memory (internal): (Digital). The total memory or storage which is accessible to the computer without human intervention.

Output: Information transferred from the internal storage of a computer to secondary or external storage.

Program: 1. A precise sequence of coded instructions for a digital computer to solve a problem. 2. A plan for the solution of a problem.

Routine: (Digital). 1. A sequence of operations which a computer may perform. 2. The sequence of instructions determining these operations. 3. A set of coded instructions arranged in proper sequence to direct the computer to perform a desired operation or series of operations.

Simulation: The representation of physical systems and phenomena by computers, models, or other equipment.

ACKNOWLEDGMENT

Definitions in this brief glossary are reproduced by the kind permission of Berkeley Enterprises, Inc., publishers of *Computers and Automation*. The complete glossary contains more than 480 definitions and may be found in the October, 1956, issue of *Computers and Automation*.

. . . the COMPUTER AND YOU

• What can electronic computers do?

• What types of computers are currently available and for what types of problem is each machine best suited?

• How can these machines aid the chemical engineer in his work?

• Must the machines be operated exclusively by highly-trained mathematicians and computer specialists, or can the average chemical engineer learn to formulate his own problems for machine solution?

In the series * of articles which follows, *CEP* attempts to bring to its readers at least a preliminary conception of the scope of these new scientific tools and some idea of their actual and potential usefulness to the chemical engineer. It is, of course, not possible in this brief review to include detailed instructions for the use of these complex machines.

However, many readers, armed with an overall background on computer techniques and possibilities, may be encouraged to undertake further investigation on their own initiative and thus not only enhance their usefulness to their companies, but further their careers as well.

The general scope covered by the authors of the various papers was purposely kept as broad as possible. An attempt was made to include material on all the main categories of computers which can logically be applied to chemical engineering problems. Thus, while Hollander and Tompkins explain the principles underlying the operation of all types of digital computers, large and small, Opler concentrates his attention on the small digital installation and Hoerl recapitulates Du Pont's experience with the use of large digital computers in the solution of chemical engineering problems. The analog type computer is discussed in many aspects by Williams and Johnson, who include a step-by-step illustration of the method used to solve an actual mechanical problem by analog methods.

The series is rounded out by a transcription of the round table discussion which followed the formal presentation of papers at Los Angeles. In this informal get-together, the authors attack some of the basic problems confronting the company which is contemplating a computer installation. Emphasis is on the role of the chemical engineer in a computer set-up and on the several main categories of available computers—their capacities, and their general fields of application.

To aid the reader in the complete understanding of this series of articles, *CEP* includes (left) a brief glossary of computer terminology.

As a further practical aid to those interested in the application of these machines to chemical engineering problems, we have added a descriptive tabulation of some of the most used computers. (See next page.) This tabulation is not to be considered complete in any way but is included to give a preliminary idea of what the various types referred to in the articles in this series comprise, and approximate costs.

How to Get Started with Computers

As soon as a company has outgrown the small accounting type punch card machines, it is almost inevitable that it will need help from the outside if it wishes to install more advanced machines. Here, there are two main avenues of approach: one can enlist the aid of independent consulting specialists, or turn to one of the Computer Service Centers which have been established throughout the country by several manufacturers of advanced computing equipment.

Experience to date has shown that large computers are "bought"—not "sold." General practice seems to be for the company considering purchase or lease of a computer to bring a sample problem to one of these Service Centers for a "feasibility study." Results of such trial runs have in many cases led to the acquisition of a large computer installation, or arrangements for access to one.

In addition to information on capacities and capabilities of the various machines, these Centers also offer consulting services, mathematical help, and courses of instruction. A planned visit to such a Center can in itself be an educational experience.

Another computer symposium of interest to chemical engineers will be held at the March 3-6 meeting in White Sulphur Springs. See Future Meetings, page 122, for details.

* This series was made possible through the efforts of chairman R. Curtis Johnson, assistant professor of chemical engineering at Washington University, St. Louis, and the authors who contributed to the symposium on the "A.B.C.'s of Machine Computation" at the recent A.I.Ch.E. Meeting in Los Angeles.

A COMPUTER ROUND-UP

DIGITAL

▼ SMALL

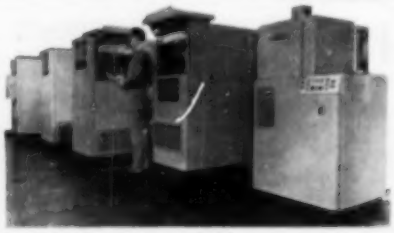
E-101 (Burroughs): desk-size; engineering, statistical, research, business applications; program storage on removable pinboard units, input from keyboard or optional tape unit; cost $35-45,000; rent $900-1,000/mo.; programming can be learned in a few days.

Univac-120 (Remington Rand): 120-digit memory (Univac-60 has 60-digit memory); wiring panel programming; punched-card input; business, production, engineering applications; cost about $100,000; rent about $1,000/mo.

602-A (IBM): punched-card calculating machine; designed primarily for business applications, as is the related all-electronic 604; these machines rent in range $250-600/mo., depending on capacity and auxiliary units.

▼ MEDIUM

650 (IBM): stored program type (magnetic drum); punched-card input and output; can be modified for magnetic tape input and output or direct printer output; rent about $3,750/mo. up, depending on auxiliaries.



Univac File Computer (Remington Rand): magnetic drum or magnetic core program storage; input can be paper or magnetic tape, punched cards, or keyboard; business and scientific mathematics applications; cost $300-500,000; rent $4,500-8,000/mo.

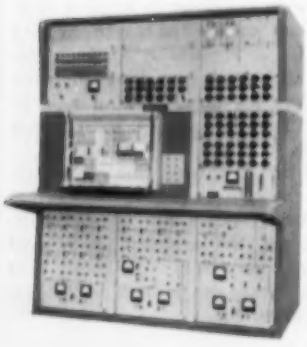
Datatron (Burroughs—ElectroData): magnetic tape and drum storage unit; input and output can be by keyboard, typewriter, punched paper tape, magnetic tape or punched card; cost $200,000 up; rent $6,000/mo. up.

▼ LARGE

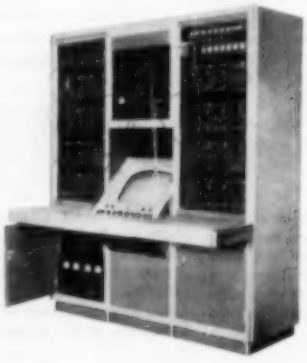
Univac (Remington Rand): input and output on magnetic tape—punched card and other information must first be "translated" to tape; unlimited applications in commercial, defense, and scientific fields; internal information storage in mercury tubes; cost $1 ½ million up; rent $350/hr. at service centers.

704 (IBM): magnetic core and magnetic tape storage; magnetic tape input and output; for scientific, engineering, business problems; rent about $30,000/mo.

ANALOG



REAC-400 (Reeves Instrument Corp.): This Reeves Electronic Analog Computer is a basic set-up. Modular construction of analog computers permit user to build up a unit of any size according to the scope and needs of the problem; basic facility costs therefore vary with the problem.



K3 Analog Computer (G. A. Philbrick Researches): Modular construction; cost of modest basic installation could be as low as $15,000. Analog computers can be considered "models," can simulate and synthesize innumerable phenoma; applications limited only by the imagination of the user. Users should have training in mathematics, methods of scaling, and knowledge of electronic circuitry.

Standards Western Automatic Computer (SWAC) circuitry being checked with oscilloscope.

What will chemical engineers need to know in the near future in order to exploit currently available computing machinery for the solution of their problems? There is little chance that the availability of these machines will make life any easier for the chemical engineer; the machines will do no more than make it possible for the engineer to learn a new and difficult field in order to solve problems he is now unable to solve (1). Specifically, how can computers help in the solution of problems in chemical engineering and related fields? Initially certain questions must be examined as

1. what can a computer do?
2. how can we tell it what to do?
3. how efficient is the process?
4. how reliable are the answers?

what you should know about DIGITAL COMPUTERS

F. H. Hollander and C. B. Tompkins

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Digital computers are all based on a simple arithmetic system. Most machines perform addition, subtraction, and multiplication; many do division; but few have built into their circuitry anything as complicated as the calculation of square roots. Logical operations are also built in to aid in the decision-making process. Finally, since communication with the outside world is necessary, operations enabling the computer to receive, and to deliver, information are included in the logical structure of the system. The most complicated decision can be reduced to a series of simple choices if explicit rules are stated. For example, the process of automatic division by a desk calculator includes a succession of simple decisions based on whether the remainder is negative or not, and which results in either an addition and shift or a subtraction. The decision process of a modern electronic machine is a development of this. Its operation requires that the mathematical representation of a problem be complete and explicit.

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The authors acknowledge valuable suggestions from R. C. Johnson, professor of chemical engineering, Washington University, St. Louis, Missouri, T. Weaver, Fluor Corp., and many others.

What Can a Computer Do?

Perhaps the most impressive fact about these computing systems is their speed of operation. It is estimated that a human operator, using a desk calculator, can produce 400 ten-by-ten decimal-digit multiplications in one eight-hour day. This includes time for recording the answer of each operation and for some simple accuracy checks. One thousand additions may be performed in the same length of time by the one calculator. By contrast, The University of California computer is able to complete 15,500 additions or 2,700 multiplications a *second*, to better than ten decimal digit accuracy.

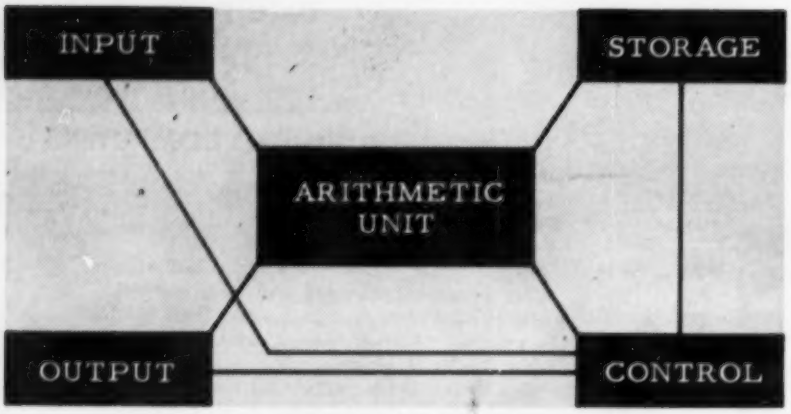

Fig. 1. Schematic representation of electronic digital computing system.

How Can One Tell the Computer What To Do?

The speeds just referred to are so high that no one can specify each operation individually in a calculation and expect to keep the computer acceptably busy. It is necessary that the machine prepare its own instructions and that the human being limit his activities to specifying to the machine how these instructions are to be prepared; this requirement is the basic one on which the necessity for decision-making by the machine (which occurs at rates comparable with its arithmetic speeds) is based. Something new in the meticulous preparation of problems is called for in order that the efficiency of the new computing systems may be utilized without frequent stops for slow human guidance.

Figure 1 represents an electronic digital-computing system. The analogy with hand computation is direct and obvious. The individual is replaced by the *control* center of the computer; the tables and work sheet become the *storage*, *input*, and *output* equipment; and the desk calculator is replaced by the *arithmetic unit*.

The storage must provide a number of identifiable locations, and these, numbering a few hundred to a few thousand, are usually numbered serially. The number which is the label of any position in the storage is defined as the *address* of the contents of that position. This storage is frequently called the *memory* of the computer.

Operations which the machine will be called upon to carry out are described as commands. An ordered sequence of commands, sufficient to carry out a calculation, constitutes a program or routine. These commands are encoded so as to have the same form as numbers within the machine; this implies that they may be stored in the memory like numbers. Coded commands are sent to the control center of the machine where they are decoded and obeyed. Numbers are normally transferred between the memory and the arithmetic unit. Since there is no distinction within the memory between numbers and commands, instructions may be sent also to the arithmetic unit for modification. Thus it is possible to use the arithmetic unit to create new instructions, to modify existing ones, or to rearrange entire programs as the calculation proceeds.

The console of SWAC with Mr. Tompkins at left, Mr. Hollander at right. Built by the National Bureau of Standards, the computer is now owned by UCLA.

It is true that almost any method for doing a calculation with the use of a desk calculator can be programmed for a digital computer. But the best method for the computer will not, in general, be the one used for the *hand* calculation.

As an example, consider the evaluation of an integral as a function of the upper limit, or the numerical solution of an ordinary differential equation. In a manual program an interval of fairly large size, and an integration formula involving differences of the integrand as high as sixth or seventh, is attractive (*2*). The digital computer program, however, will be much easier to encode if a simple trapezoid rule is used, with an interval one hundredth or even one thousandth as great. The tremendous advantage in speed of the electronic computer makes this approach frequently acceptable.

Limitation in storage space and facility with elementary arithmetic operations affect the general methods chosen to carry out more complicated operations. Thus, to find a square root, one guesses an answer (or chooses an approximate answer from a very small table), improves it according to some iterative formula, and tests the result (forcing the machine to make a simple decision), and goes through the improve-test cycle again if required. One specific set of formulas used for this follows:

To determine $\sqrt{u}$, start with an approximation x_0. An approximation x_i not close enough to the final answer is improved by the formula $x_{i+1} = \frac{1}{2}(x_i + u/x_i)$. The improved approximation is tested by checking the absolute value of the difference between it and x_i against a tolerance set as part of the routine; this approximation is to be improved (according to the formula above) if

$| x_i + 1 - x_i | \geq h$, where h is the preset tolerance.

Thus, if $u = 2$, $h = 0.002$ and $x_0 = 1.500$, the calculation would go as follows to three decimal places.

$x_1 = 1.417$,
$| x_1 - x_0 | = 0.083 \geq 0.002$,

$x_2 = 1.414,$

$| x_2 - x_1 | = 0.003 \geq 0.002,$

$x_3 = 1.414.$

$| x_3 - x_2 | = 0.000 < 0.002.$

Since the last inequality is in the acceptable direction, the value x_3 is chosen as the acceptable approximation to $\sqrt{2}$.

Other techniques, which the user of large computers must learn to adopt in order to conserve storage space and computing time, include the continued fractions and approximating polynomials of the Chebyshev type instead of tables or Taylor series expansions for the generation of many standard functions. Hastings and his associates have listed many rational approximations of remarkable accuracy and simplicity (*3*), and Teichroew and others have written about continued fraction expansions (*4*). Reference is made here to an unpublished expansion due to T. H. Southard for the value of the equianharmonic case of the doubly periodic Weierstrass γ-function $\gamma(z)$ along its real half period. This case is tabulated in a classical text (*5*) with 180 entries, furnishing an accuracy of five significant decimal digits for most of the range. However, Southard points out that if we write

$$y = \frac{1}{z^6},$$

and

$$H(y) = 0.99999\ 990 + 0.03571\ 4504\ y + 0.00009\ 80386\ 9\ y^2 + 0.00000\ 01932\ 0\ y^3,$$

then for the equianharmonic case $\gamma(z)$ may be approximated to seven significant decimal digits by $H(y)/z^2$ along the real half period $0 \leq z \leq 1.53$.

Choice of Machine

The choice of a mathematical method and of arithmetical techniques will depend in part on the problem and in part on the capabilities of the available machine. Operations which the machine is capable of performing are chosen as a compromise between the desirability of high arithmetic versatility and speed and the need for engineering simplicity.

The machine will possess a storage unit, an arithmetic unit, and a control unit. (Means for inserting or removing information can be ignored at this point.) The arithmetic unit consists of two main parts: the accumulator, designated by the letter *A*, and the multiplier, designated by the letter *M*. The addition operation will take place in the accumulator; multiplication may be performed by providing in the engineering design for a sequence of additions of the multiplicand, accompanied by the appropriate shifts of the partial sums and controlled by the digits of the multiplier. The positions in the memory will be addressed by numbers, and the storage capacity of the memory must be adequate for the problem in hand and the attack chosen.

Basic Commands

There are ten operations which a modern automatic machine must be capable of carrying out by interpreting coded commands. One set of digits of the command will refer to one or more addresses in the memory; another set will consist of an encoded instruction, which, when properly decoded by the control unit of the machine, results in the carrying out of the specified operation. The digits of these two parts will be run together to form a single number. These encoded commands will be placed in the storage unit of the machine, and the designator of a command will be simply that address of the storage system at which the command is stored. Commands in this form were first proposed by Burks, Goldstine, and von Neumann (*6*).

All machines in existence today include the accompanying basic commands in some form, and these machines, depending on their complexity and

Data Processing

DIGITAL COMPUTERS

BASIC COMPUTER COMMANDS

1. $w(x) \rightarrow A$
2. $w(A) + w(x) \rightarrow A$
3. $w(A) \rightarrow x$
4. $w(A) - w(x) \rightarrow A$
5. $w(x) \rightarrow M$
6. $w(M) \cdot w(x) \rightarrow A$
7. If $w(A) \geq 0$, JUMP
8. $w[S(A)] \rightarrow S(x)$
9. JUMP
10. STOP

• The first of these commands clears the accumulator, *A*, and inserts into it a number previously held at a designated address. The operation leaves the number unchanged in its storage position in the memory.

• The second operation adds to *A* the number at a specified address, without clearing *A*. The addend remains unchanged in the memory.

• The third operation is the inverse of the first. It calls for the storage of the number in *A* at a specified address in the memory. The execution of these three commands in sequence constitutes the operation of addition in the computer.

• The fourth operation is similar to the second: it specifies subtraction of a number from the contents of the accumulator.

• The fifth operation consists of replacing any number in the multiplier, *M*, by a number from a designated address in the memory. Again the number is unchanged in the memory position, and this operation has no effect on *A*.

• The sixth operation clears *A* and inserts into *A* the product of the number in *M*, as multiplier, and the number at a specified memory address, as multiplicand. The number in *M* is destroyed during the operation, but not the multiplicand. The sequence of operations involved in setting up *M*, creating the product, and storing the answer constitutes the complete operation of multiplication in the computer.

• The seventh operation requires first an understanding of what is meant by normal sequencing of commands. A program is set up in a fixed sequence, and stored in such a way that the machine will automatically carry out each instruction in the order of this sequence. This is accomplished by a counter in the control unit, which keeps track of the address of the instruction currently being carried out. Thus, there must be included commands which order the machine to depart from the normal sequence. If this were not so, it would be impossible to recycle, and one command would have to be written for each arithmetic operation performed by the machine. The seventh operation in the present discussion is one which provides for a conditional alteration of sequence. If the number in *A* is negative, there will be no change of sequence; but if the number is nonnegative, the machine passes to the instruction stored at the address specified by the command being obeyed. After each command is carried out the control unit passes to the next higher numbered storage cell for the next instruction unless it has been ordered by the command just carried out to depart from the standard sequence. Thus, recycling and alternate sequences are made possible.

• The eighth operation transfers information from *A* to the storage unit, except that the information transferred from *A* is restricted to the digits concerned with the address of a command. Hence, no matter what is in the accumulator, those digits in the storage position having to do with the operation will not be changed; the only change is a change in address. This operation permits the modification of a specific arithmetic command to allow its application to any set of numbers stored in the memory, without the need of writing an explicit command for each number to be operated upon.

• The ninth operation provides for an unconditional change of sequence, regardless of the contents of *A* or *M*.

• Finally a command is provided to tell the machine to stop calculations. Without this command the machine would proceed through a sequence of meaningless and perhaps harmful calculations (harmful in the sense of destroying useful results stored in the memory).

WHAT COMPUTER?

The selection of the right computer demands a knowledge of computers and of the technical application expected of them. One cannot select the right computer without having something very close to an ability to program and code one's own problem for all competing computers.

expected applications, include additional commands. The requirement that a few written commands direct a long calculation is met by breaking the calculation down into its veriest elements, as they appear in the operations just described, by reusing commands, by using the arithmetic unit to modify their addresses, and by employing the various commands available to cause the machine to repeat portions of the calculation (with some addresses modified perhaps) either unconditionally or under its own simple decision as to the necessity of this repetition.

Programming

The general programming procedure will vary only in minor details for any given problem in going from one digital calculator to another. Programming will begin after the mathematical formulation has been completed. The methods must involve only arithmetic operations. For example, a differential coefficient must be replaced by its finite difference approximation. Decisions on the use of approximating functions or tables, and investigations into the effects of such approximations, errors of round-off, or errors of truncation of series, are all properly made at this time.

The next phase of the solution of a problem is usually the creation of a schematic program or a flow chart. This will be essentially a complete picture of all the operations a machine will perform in the solution of the problem. All branch points or places where a decision is required of the machine must be displayed, as well as the details of each possible route which the calculations may take. The particular machine to be used has some influence on this flow chart. A schematic representation of a problem solution at this stage is applicable (with at most minor changes) to any digital computer.

The final stage is the translation of the instructions on the flow chart into the actual language of the computer. Encoding of the instructions is carried out with a specific machine in mind. Considerations such as the existence of a divide command, the need of taking square roots, and the creation of special subroutines not available in the library of coded routines must all be taken into account. The problem of what to do if requirements exceed the available storage space is a most embarrassing one which often crops up to plague the coder. Ingenuity in saving space should always be part of the stock in trade of the best programmers and coders.

Additional details will involve a consideration of the form which the data of the problem assume and the means by which they will be fed into the computer, as well as the form in which the results are desired from the machine. A great variety of input and output mediums is available, and many machines have provisions for using several types. The amount of output must be carefully planned. Output transfers are slow compared to computing speed, hence, for efficiency, no more material should be produced than is needed. It is easy to produce large amounts of printed record merely by giving the instructions to the machine. The embarrassment of riches which results is the generation of far more printed material than anyone can read.

How Efficient Is the Machine Computing Process?

The major criterion of efficiency for a chemical engineer will lie in the answer to two questions: (1) how many people will one machine replace, and (2) how many problems otherwise beyond solution can be solved with machines. The answer to the first question is almost certainly that no personnel will be released by use of a machine, and that acquisition of a machine will most likely lead to increase in the payroll. The answer to the second question is there is no doubt of the existence in all science and engineering of large and important classes of problems just beyond the capabilities of computation without automatic machines which are now solvable on machines (*1*).

How Reliable Are Computers?

The outlook for reliability is good. New components seem more stable and less subject to wear than older ones; etched circuitry gives promise of decreasing the number of assembly mistakes; machines are checking out the logical circuitry of other machines and avoiding some of the human errors which are so hard to find; decreasing power requirements and particularly decreasing voltage requirements imply less chance of ruinous strain on components such as resistors and diodes; finally, it seems likely that methods of detecting faulty or potentially faulty components will improve. Any fear that the reliability of modern computers is too low to permit the user to trust the answers obtained seems unfounded; their reliability is certainly greater than that of any other computational facility—including human beings! There is even less ground for concern that their reliability is so low that their use is not economical for a firm with enough problems to occupy a modern computer full time; they certainly provide calculation at the lowest presently attainable cost per correct arithmetic operation.

Presented at A.I.Ch.E. meeting, Los Angeles, California.

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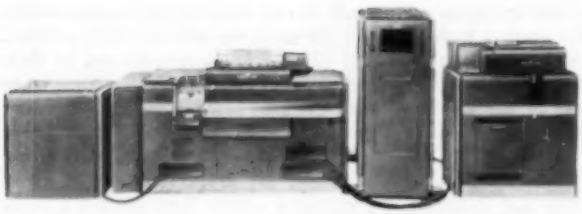


IBM's CPC (Card Programmed Calculator), a transition machine between small and larger computers. (See page 450.)

. . . the small DIGITAL COMPUTER INSTALLATION

Small digital computer installations often provide the experience and justification required before acquisiton of a larger machine. In general, the problems solvable are not limited by scope, but by the allowable solution time. Ingenious techniques have been devised to simplify machine instruction and to extend its range. Costs are relatively low, especially when an installation can be shared with an accounting department. Advantages, disadvantages, and limiting factors are discussed.

Ascher Opler | The Dow Chemical Company, Pittsburg, California.*

The small digital computer is generally a punched-card machine devised for accounting purposes but perfectly adaptable to scientific purposes. As opposed to the larger machines which operate with an internally stored program (or sequence of instructions), these are controlled by wire-programming or card-programming. In the former, one arranges a group of patch cords on a control panel to obtain the desired sequence. Panel wiring, once the mainstay of the computation planner, is becoming a lost art. Its great advantage lies in the almost limitless versatility made possible by arrangements of two- to three thousand available terminals. Card-programming actually is a special form of wire-programming. The control panel is connected in such a manner that special punches on the cards set up (by card actuated relays) special subcircuits to carry out selected operations. The big advantage here is that the versatility of the machine is used to permit the programmer to write out sequences of instructions (from a fixed list) that will produce the desired results without recourse to moving a single wire.

Characteristic of the small digital computers is their small internal storage capacity (100 to 500 decimal digits) and their slow speed of operation (2 to 150 calculations/min.). However, in principle and in fact, these machines can do everything the larger machines can. Since partial results or other information to be stored may be punched onto cards, held and later fed into the same machine, in a sense the storage capacity is infinite. With sufficient time and intermediate manipulations, any problem solvable on a machine like Univac is solvable on one as small as the 602-A. In practice, time for calculation and intermediate manipulation limits the size of problems attacked. Except for major research calculations, an upper limit of two to eight hours per repetitive problem prevails.

* Mr. Opler is associated with the Research Department, Western Division.

The 602-A (IBM) calculator. Description on page 450.

Low Cost

The rental of a small punched-card machine naturally varies with its speed and capacity. Actual machine rentals run from $300 to about $2,300 a month. In addition to the computer, there is needed a group of basic machines for punching and verifying cards, reproducing and manipulating them, and for preparing printed reports. These will run from $200 to $800 depending upon the speed and versatility required. To total machine costs of $500 to $3,000 a month, should be added an amount for labor and overhead that will be roughly in the same order of magnitude as the total machine rental.

Although purchase is possible for some equipment, rental generally is preferred because of the rapid obsolescence in this field. Computers only three years old are generally left far behind today's machines on every score. Renters find little difficulty in replacing their old equipment, where the added expense is warranted.

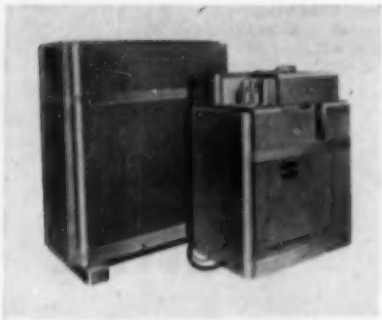
Scope

Following are some examples of the power of these simple machines. With examples from the published literature or from the operating experience of one small computer installation, two lists have been prepared of operations performed on the three most frequently used small computers: namely, the IBM 602-A Calculating Punch, 604 Electronic Calculating Punch, and the Card Programmed Calculator. Mathematical operations are shown in Table 1. Table 2 shows some calculations arranged according to their chemical engineering significance.

Limitations

Since these operations appear to be quite comprehensive, it would be only fair to state that in most cases they are limited in scope. Twenty simultaneous equations may be handled practically; one hundred equations may not. One-dimensional, time-dependent, partial differential equations may be solved explicitly. Practical implicit solutions and those involving two or more dimensions are generally beyond the capacity of these machines. Polynomials with terms beyond the fifteenth degree generally will not be worth attempting, and so on.

To give a closer view of the scope



The 604 (IBM) small punched-card calculator.

of these small computers, two examples can be presented: one falls quite properly within the scope of these computers; the other seems to require a large-scale machine, yet has been actually carried out with the smallest of the small computers.

The first example concerns the design of a proposed high-temperature reactor, in which selection of the proper refractory caused considerable concern. Since high heat transfer rates were required, an elaborate series of solutions of the applicable form of Poisson's equation was planned. An elaborate wiring panel was devised that permitted extremely simple operation. One merely fed in a single punched card giving the initial temperature profile, the time and space increments used, and the selected heat transfer coefficient. Operating unattended, the machine would run for one to two hours and prepare and punch a complete point-by-point solution. Each run produced several hundred solutions; several dozen runs were made in the course of investigating the whole range of behavior of these materials.

The second example involves the solution to the equations of kinetically controlled ion exchange or the analogous solution for heat transfer from a flowing stream to a bed packed with spheres. Although Henry C. Thomas of Yale (*1*) had developed the form of the solution to these partial differential equations, a complete numerical evaluation in the ranges of interest to engineers working with ion exchange was not available. The complexity and scope of the equations may be gathered from Table 3, which represents one form in which the rigorous solution can be approximated. Nevertheless, *ten thousand sets* of solutions to *each* of the two equations were produced, checked, and printed by these small computers. The method used was that of parallel computation. If, for example, ten thousand calculations of $A^2/(B+\sqrt[3]{C})$ are required, ten thousand cards containing A, B and C are prepared. The square of A, the cube root of C, and the sum of $B+\sqrt[3]{C}$ are calculated separately. Then the final desired result is calculated in a separate operation.

Points of View

Small computer installations may be viewed in two ways: as an introductory step between no computer and an eventual large or intermediate machine, and as a satisfactory working installation of proper scale.

Serving as a first step toward a full-fledged computing organization is the most common function of small computer installations. Attractive features of such a move are the following.

1. Since most large or moderate-sized organizations already possess punched-card machines in their accounting departments, the first step is the operation of a computer group on a time-sharing basis. Most accounting departments profit in two ways by this arrangement: (1) the machines are more fully utilized, and (2) the know-how gained by their technical personnel can assist them when they get into more complex accounting problems.

2. Such a computer installation is expandable. As usage increases to a few problems a month, then to a few a week, and eventually to a daily routine, more operators can be hired and additional small machines can be rented. The gradual expansion is paced by gradually increasing costs with a reasonable proportionality.

3. Another way to use the small computers to advantage is as adjuncts to large-scale machines. Small computers can be used to work out the method later employed on a big computer; thus hundreds of dollars are saved by avoiding much trial-and-error work on the expensive machine. Some minor precalculation may also be done economically on small computers.

Small computers, however, need not serve as a transition stage exclusively. There are many technical installations with such machines as "regular" computers, and no plans have been made to replace them. One machine, kept busy at technical computations eight to twelve hours a day, can probably handle the problems of an average organization with 100 to 300 technical men. Routine calculations like those of mass spectrometry and statistics may be interspersed with the running of special problems.

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Presented at A.I.Ch.E. meeting, Los Angeles, California.

Table 1.—Problems Solved by Small Digital Computers

(Arranged by Mathematical Types)

- Roots of polynomials (real and complex)
- Roots of transcendental equations
- Solution of trigonometry problems
- Functions: generation and interpolation
- Simultaneous linear and nonlinear equations
- Matrix calculations—inversion, multiplication, addition, and location of latent roots
- Fourier analysis and synthesis
- Evaluation of convergent and asymptotic series
- Ordinary linear differential equations
- Partial differential equations
- Simultaneous differential equations
- Integration
- Solution of integral equations
- Continued fractions
- Inequality matrices
- Problems in number theory
- Problems in symbolic logic
- Calculation of statistical parameters
- Analysis of variance

Table 2.—Problems Solved by Small Digital Computers

(Arranged by Types)

- Equations of state
- Vapor-liquid equilibrium constants
- Vapor-liquid equilibria of mixtures at various temperatures and pressures
- Plate-by-plate distillation calculations
  - Continuous and batch distillation
  - Binary and multicomponent distillation
  - Effect of nonidealities
- Diffusion
- Heat conduction
- Fluid flow
- Heat transfer in flowing systems
- Ion exchange column calculations
- Adsorption calculations
- Reaction kinetics and reactor design
- Thermodynamic calculations
- Mixing and extraction

Table 3.—Equations for Kinetically Controlled Ion Exchange Column Performance

$$\lambda = \frac{f(z_2)+B}{f(z_1)+f(z_2)+B-A}$$

$$\omega = \frac{f(z_2)+C}{f(z_1)+f(z_2)+B-A}$$

where

$$A = \frac{1}{(rt)^{1/6}+(rst)^{1/6}}$$

$$B = \frac{1}{t^{1/6}+(rst)^{1/6}}$$

$$C = \frac{1}{(rs)^{1/6}+(rst)^{1/6}}$$

$$f(z) = \sqrt{\pi}[1-H(z)]e^{z^2}$$

$$z_1 = (rt)^{1/6}-(s)^{1/6} = (s)^{1/6}\left[\left(r\frac{t}{s}\right)^{1/6}-1\right]$$

$$z_2 = (rs)^{1/6}-(t)^{1/6} = (s)^{1/6}\left[(r)^{1/6}-\left(\frac{t}{s}\right)^{1/6}\right]$$

The General-Purpose Analog Computer is becoming a vital tool in the study of chemical process control systems. Here is an exposition of how these machines operate and what type of problem they are best adapted to solve. To understand and operate the analog computer, the chemical engineer needs little knowledge beyond that to which he has already been exposed. A basic understanding of differential equations and of the elements of electronics, plus the solution of four or five relatively complex problems under the tutelage of someone thoroughly familiar with machine operation, is usually sufficient to make one a moderately proficient machine operator.

THE GENERAL-PURPOSE ANALOG COMPUTER

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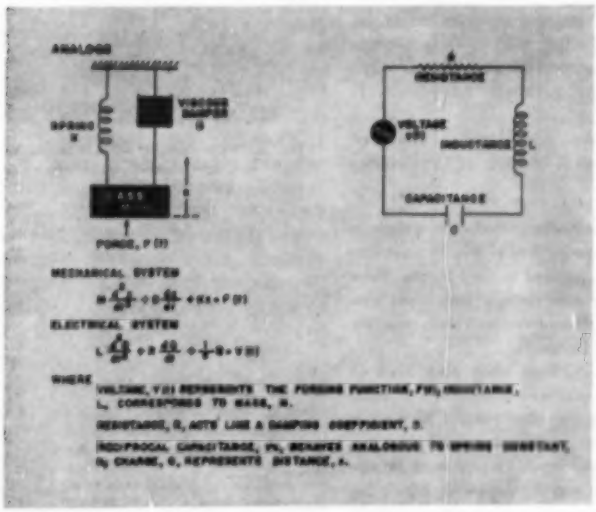
Institute of Technology, U.S.A.F. Wright-Patterson AFB, Ohio

Fig. 1.



The analog computer operates by simulating in the action of easily manipulated and measured electrical quantities the behavior of the pertinent variables of a fluid flow system, a mechanical device, a chemical reactor, or any other system whose actions are to be investigated. Since this simulation is a continuous one, it allows the direct inclusion into the same solution of such concepts as distance, velocity, acceleration, or any other similarly related variables. This is in contrast to the digital computer which, through its performing of actual arithmetical operations with numbers, functions discontinuously and thus can only approximate higher order effects.

The electronic differential analyzer, which is a type of general-purpose analog computer, is admirably suited to the solution of ordinary differential equations or better stated—systems of simultaneous ordinary differential equations, linear or nonlinear with constant or nonconstant coefficients. Nonlinearities in the equations and the presence of nonconstant coefficients increase the complexity of solution on these computers only slightly (*4B*). Again, this is a contrast to digital computer solutions. Other problems which can be solved on these machines include algebraic equations and partial differential equations.

Analog-computer results are normally presented graphically as a continuous plot of the variable quantities vs. time or as plots of one of the dependent variables of the problem vs. another. In many instances this method of presentation is most convenient for engineering use. The graphical representation of results has another important aspect. It is relatively easy for the engineer, as he operates the analog computer, to visualize the results as the actual dynamic response of the physical system under investigation.

Fortunately for the analog computer, it so happens that practically all the important automatic control problems resolve themselves into systems of simultaneous ordinary differential equations, linear or nonlinear, with constant or nonconstant coefficients; this is exactly the type of problem best suited for this machine. In addition, solution of these equations seldom requires great accuracy. A picture of the type of system action to be expected rather than the absolute numerical magnitude of such action is most important to the investigator. Thus the limitation of these computers to three- or four-place accuracy is little hindrance to their use.

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Fig. 2a. Symbolic representation of operational amplifier.

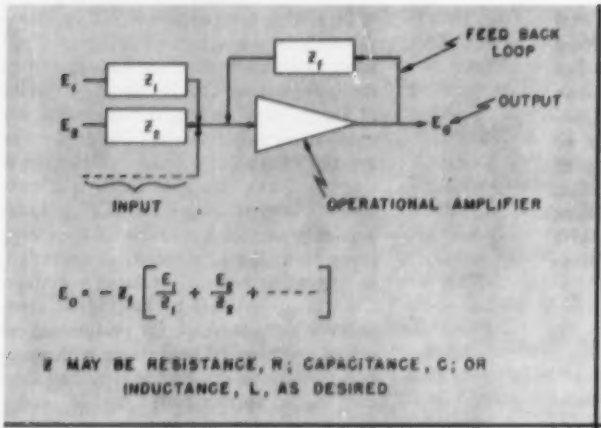


Fig. 2b. The operational amplifier as an adder.

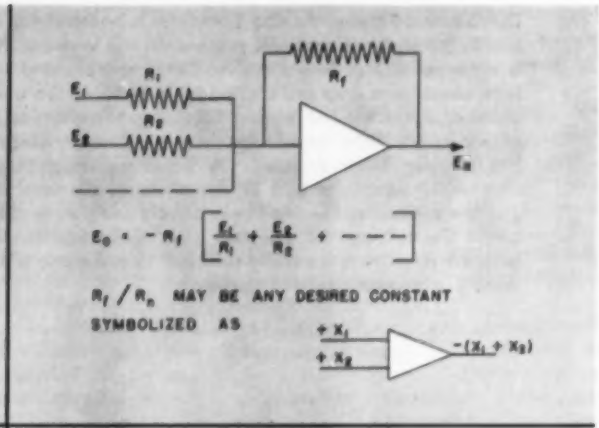


Fig. 2c. Integration on the operational amplifier.

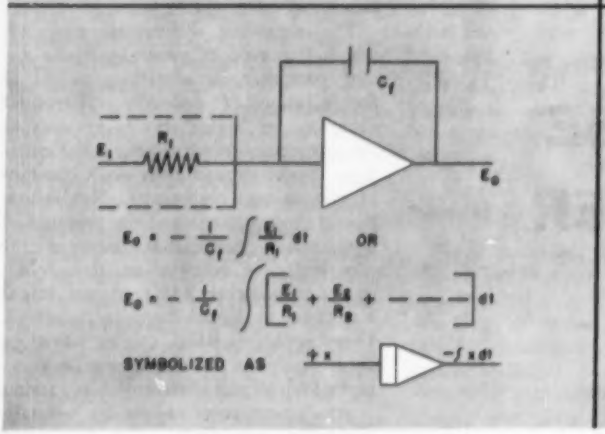
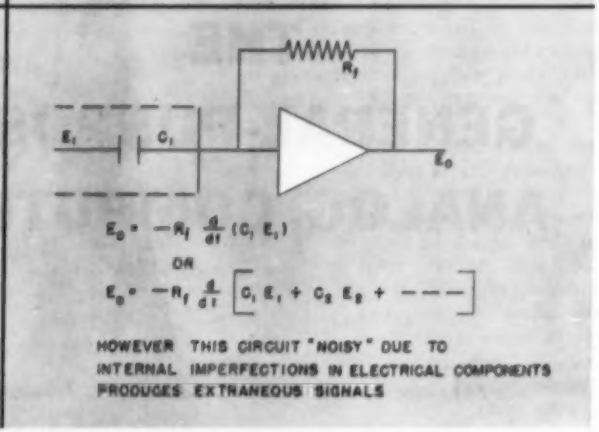


Fig. 2d. Simple differentiation on the operational amplifier.



Finally in the solution of this type of problem the analog computer is far faster than digital equipment and can handle the existing nonlinearities more readily. For instance, with proper recording equipment the Reeves Electronic Analog Computer (REAC) enjoys a speed advantage of approximately 200:1 over the IBM Card Programmed Electronic Calculator for similar simultaneous differential equation problems (6C).

How the Analog Computer Operates

It is a fairly common practice to represent a mechanical system or other system under study by means of an appropriate electrical circuit whose voltage or current then behaves as does the dependent variable of the system under investigation (Figure 1). Thus, the algebraic or differential equations, as the case may be, of the two systems are similar if not identical in form.

The electronic differential analyzer is based upon the operational amplifier, a very high gain d.-c. amplifier whose properties can be modified by the addition of the appropriate input and feedback electrical elements, such that the output voltage of the amplifier will represent some mathematical function of the input voltage or voltages. Operations such as differentiation, integration, and algebraic summation can easily be accomplished. Figure 2a shows a general representation of the circuit capable of performing these mathematical operations.

The electronic differential analyzer consists of several of each of the following devices:

a. Operational amplifiers which can deliver a continuous negative sum of one or more variable voltages applied to their inputs. These amplifiers can also multiply each input voltage by some desired constant. They are symbolized as in Figure 2b.
b. Operational amplifiers which have been altered by the addition of condensers in order to give a negative time integral of the sum of one or more different variable voltages applied to their inputs. Again multiplication by a constant may be employed (Figure 2c).
c. Potentiometers which give precision multiplication of any variable voltage by any con-

Fig. 3. Approximate differentiation on the operational amplifier.

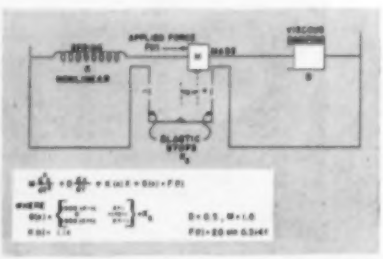


Fig. 4. Solution of a typical problem.

stant less than one. Combinations of (a) and (c) thus will permit multiplication by any desired constant value.

d. Electronic multipliers or electromechanical servomultipliers for performing multiplication and division by variables. Electronic multipliers are faster and more versatile but often are less accurate than are servomultipliers.

e. Relays and diodes for use in simulating such nonlinear effects as hysteresis, backlash, diode space, true time delay, etc. (48).

Several of the devices just referred to are now interconnected by means of wires such that the differential equation of the voltage in the completed circuit duplicates or closely approximates the differential equation of the system being simulated. Therefore, the variation of the output voltage of the computer when properly plotted represents the solution which would be obtained from the equation of the mechanical or other system under investigation.

How to Differentiate

Figure 2d shows how the mathematical process of differentiation can be represented on the operational amplifier. However, the accuracy of this representation is subject to noise or extraneous signals in the circuit. Figure 3 shows an approximation which, however, usually gives better results for the operation.

For this reason the method of solution carried out on the electronic differential analyzer amounts to repeated integration rather than to the repeated differentiation, commonly employed in obtaining an analytic solution to a differential equation. This fact is made evident in the accompanying example.

Since the operational amplifier thus represents specific mathematical operations, the action of the electronic differential analyzer is essentially a mathematical rather than a physical simulation of the system being studied.

Illustrative Example

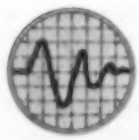
A simple mechanical system, involving the oscillation of a mass (Figure 4) rather than a chemical system, has been chosen for illustrative purposes, because the differential equations of such mechanical systems are usually more adaptable to discussion. The assumed presence of nonlinearities in the example system would make it difficult to solve the equations by ordinary analytic means.*

* This system is not original with the present authors, having been originally presented as an example in the descriptive material put out by the Boeing Aircraft Company as advertising material on one of its analog computers. However, the computer solution as presented is original, as is also the variation of the problem assuming inelastic stops.

For illustrative purposes it has been assumed that the limits to oscillatory motion of the mass (to be termed "stops") are perfectly elastic, not absorbing any energy from the system. These stops are represented mathematically by the term $G(x)$. Inasmuch as the restoring force applied to the mass by the spring is proportional to the displacement of the mass from the equilibrium position, the term $K(x) = 1.1 \mid x \mid$ further complicates the solution of the problem by analytic means. As will be demonstrated, the presence of elastic stops and of the nonlinear spring effects does not greatly complicate the setup of the problem.

In order to prepare the equation of motion of the system for analog computer solution, it is desirable to rewrite the equation

$$M\frac{d^2x}{dt^2} + D\frac{dx}{dt} + K(x)x + G(x) = F(t)$$



Data Processing
ANALOG COMPUTERS

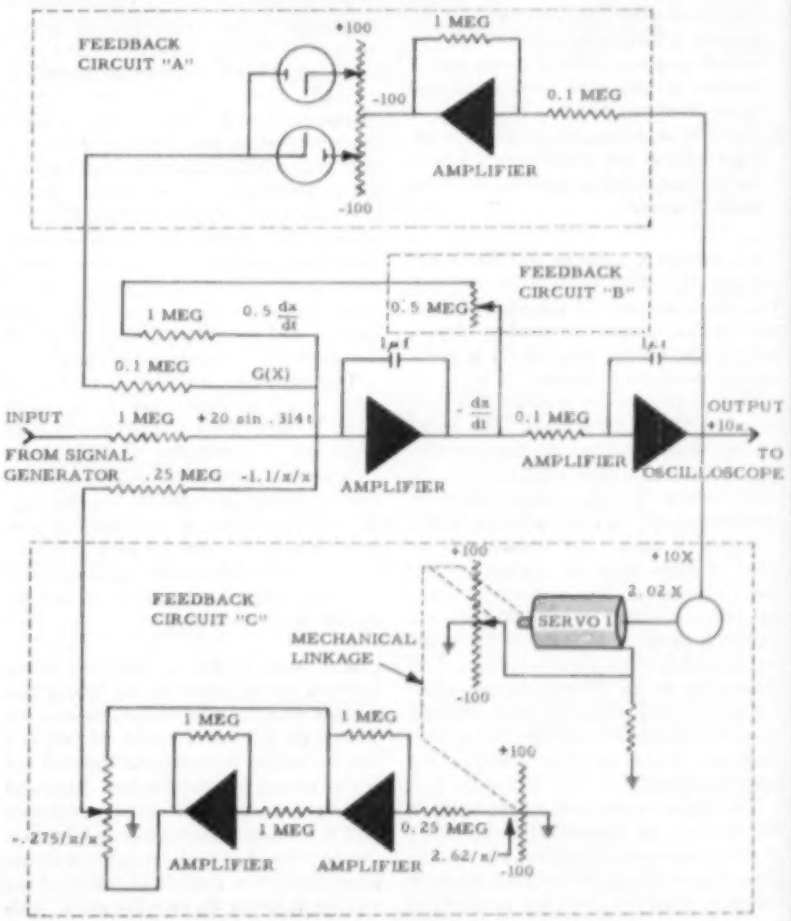
in the form:

$$\frac{d^2x}{dt^2} = -\frac{D}{M}\frac{dx}{dt} - \frac{K(x)}{M}x - \frac{G(x)}{M} + \frac{F(t)}{M}$$

or, substituting values for the parameters as given in Figure 4,

$$\frac{d^2x}{dt^2} = -0.5\frac{dx}{dt} - 1.1 \mid x \mid x - G(x) + 20 \sin 0.314t$$

Fig. 5. Solution of a typical problem.



The next step in the preparation of the circuit diagram is to assign networks of electrical components representing each term on the right side of the equation. These terms are summed through the combining of their output voltages at the input of the first integrating amplifier, making them equal to d^2x/dt^2. This summation is shown in Figure 5. Since the output of the first integrating amplifier is the negative time integral of the sum of the inputs, the output of the integrator is $-dx/dt$. This quantity is integrated again in the second integrating amplifier and multiplied by 10, thus producing $+10x$ at the output of the second integrator.

The electrical component networks which, with the two integrating amplifiers complete the computer diagram, are connected as follows:

a. $-.5\ dx/dt$: This term may be formed by attenuating the output of integrator one by means of a potentiometer set at 0.5 megohms.

b. $-1.1\ |x|\ x$: In order to form this term it is necessary to first form $|x|$ and then multiply this quantity by x and adjust the product by the necessary constant multipliers. Both the absolute value of $x(|x|)$ and the product $|x|\ x$ can be obtained by using a servomultiplier.

c. $G(x)$ is formed by a diode limiter circuit that produces a zero output while $-1 < x < 1$ and the proper output for x greater than or less than ± 1 respectively (when x is assumed to be affected by the elastic stops).

d. $f(t) = 20 \sin 0.314t$. The generation of the input signal in such a wave form is done in an auxiliary frequency generator not shown in the diagram.

No attempt is made to describe in detail the operation circuits so evolved. The main purpose of the example has been to demonstrate the method of prepairing the wiring diagram of a problem for computer solution.

The solution of the problem described above is shown in Figure 6. The center tracing shows the actual physical displacement of the mass oscillating at the elastic limits. The top tracing shows its absolute velocity at corresponding times.

Figure 7 shows the solution of the same problem with the exception that the stiffness of the mechanical stops has been increased by a factor of five. Figure 8 shows a solution of the problem in which oscillation is prevented by absorption of the kinetic energy when the mass strikes inelastic stops. Results shown in Figure 8 were obtained from a modified circuit of approximately the same complexity as that of Figure 5.

The reader is referred to the texts in this field for the theoretical development of the operational amplifier, for a complete discussion of the solution of more complex equations, and for methods of simulating nonlinear effects, such as absolute value, etc. (*3B, 4B, 8B*) mentioned above.

Experienced analog-computer operators can wire such machines directly from the differential equation of the system being simulated, as just noted, thus no complicated programming is necessary as is the case with digital equipment.

Considerations in Machine Utilization

MACHINE CAPACITY

It is possible to purchase electronic differential analyzers as custom installations of any size and assortment of components desired. It is more common, however, to purchase standard units of a convenient size. Provision is made in these latter units to allow them to be interconnected to other units to form a computer of any desired complexity. A typical commercial, general-purpose electronic differential analyzer has from twenty to twenty-four operational amplifiers. Of these operational amplifiers, usually seven to ten are equipped to serve as integrators and the remainder as summing amplifiers. Considerable flexibility is usually provided, however, so that the computer operator can obtain maximum utilization of the equipment in most problems. Computers intended for solving linear differential equations normally contain approximately twenty potentiometers to allow constant coefficients to be set in a problem. Units for nonlinear solutions include combinations of servomultipliers, electronic multipliers, arbitrary function generators, resolvers for performing trigonometric operations, and other necessary equipment. A computer laboratory capable of solving a wide variety of problems must have a well-balanced assortment of all the above-listed items of equipment.

The computer installation needed to solve many problems has to be quite large in size. This is particularly true when one is attempting to solve problems of the multistage, multicomponent type common in chemical engineering. This is true because the complete system must be represented as a group of simultaneous differential equations and all these equations must be solved together on the computer.

In a recent problem in distillation column automatic control solved by the authors four complete R.E.A.C.'s were necessary to solve the problem for a five-plate column (*5C, 6C, 7C*). One was needed to simulate the controller, and one to account for condenser time delays and feed input changes, while the other two were used to calculate the composition and flow rate changes within the column. Calculations for ten plates would have required an additional two machines to handle the extra five plates. Addition of another component for the five-plate column (i.e., a three-component mixture) also would have required two additional machines since the three component equations are approximately twice as complicated as are two component equations. Thus it is doubtful if calculations for large multicomponent columns will ever be carried out on analog computers by present-day methods since the machines range in price between $25,000 and $50,000 for a complete unit

These machines are admirably suited, however, for this type of calculation and their use thus will be insured as long as the problems to be solved can be kept to a reasonable complexity. Also, the development of a procedure for scaling down the effects of many plates so as to fit a machine of reasonable size would achieve a major break-through in this field and could lead to the rapid simulation of every possible chemical process control problem.

TIME AND AMPLITUDE SCALES

The two most important elements other than machine size to be considered in preparing a system of equations for analog-computer solution are:

a. Time scale or the speed of solution compared to the speed of the simulated system.

b. Amplitude scale or the size of machine voltages compared with magnitude of the variables of the simulated system.

It is necessary to consider these since the optimum speed of operation of the computer is, for example, much slower than that of a small spring and much faster than that of the fluid flow system of a large distillation column. Since the computer should be run at its optimum rate rather than at the natural rate of the simulated system, a time scale change is necessary. The amplitude scale concerns the adjustment of the magnitude of the problem variables to allow the computer amplifiers to operate at desirable voltage levels. If either of these factors is not properly handled, an analog computer cannot give satisfactory results.

Time Scale

In choosing a time scale at which to operate a particular problem, many questions must be considered. Usually these conflict and a compromise must be made.

Some of the things to be considered are:

a. Errors in integrations are accentuated by long computer runs.

b. Slowly varying outputs of integrators are invariably associated with low-input voltages and often with very low potentiometer settings in the problem, and thus with the largest possible percentage errors in the potentiometer setting.

c. Higher frequencies contribute to phase shift in the operational amplifiers and have the same

influence as "negative damping," i.e., they cause instability in the computer.

d. Servo devices used for multiplication operate satisfactorily only at quite low frequencies.

e. The dynamics of recording devices must be considered so that transients in the recorder response do not affect the recording.

Thus, some factors mentioned above indicate that problem operating speeds should be high; others, that problem operating speeds should be low. A compromise must therefore be made.

It is apparent from the number of considerations in choosing the time scale at which to run a problem that no simple rules can be laid down to provide a cookbook method to adjust the speed of solution of a problem. A few simple rules can be stated that will help however. These are:

a. Problem frequencies (in a problem having an oscillatory solution) of approximately one cycle in six seconds are often considered to be optimum.

b. Linear problems with galvanometer-type recorders can usually be run at appreciably higher speeds than suggested in (a) above.

c. Problems using servomultipliers and servo-driven recorders frequently must be run at speeds slower than suggested in (a) above.

In the final analysis, experience in using the computer is the greatest aid in choosing an optimum time scale at which to run problems. This is particularly true in more complex problems wherein several natural frequencies are present in the problem.

Amplitude Scale

The choice of proper amplitude scale for a problem is of equal importance as the choice of time scale. It should be made following the time-scale change, if any, but before any attempt is made to wire the problem to the machine. The following points should be kept in mind:

a. Voltage levels throughout the machine should be kept at an optimum value; for instance, the normal operating range of a REAC is ±100 v. Voltages near zero should be avoided and those in excess of 100 should be avoided to prevent overloading the amplifiers.

b. The choice of amplitude scale should be made in a manner that will preserve as much as possible the relation between the physical system and the system wired into the computer. This permits a ready interpretation of voltages read from the computer directly in terms of the units of the problem; i.e., feet, pound, seconds.

c. The system used in adjusting scale should be sufficiently simple that no confusion may arise in its use.

The simplest scheme known to the authors for amplitude scale adjustment also seems to be the best method. The

Circuit designers must be ever alert to the possibility of encountering "loading errors" and to the frequency response limitations of equipment.

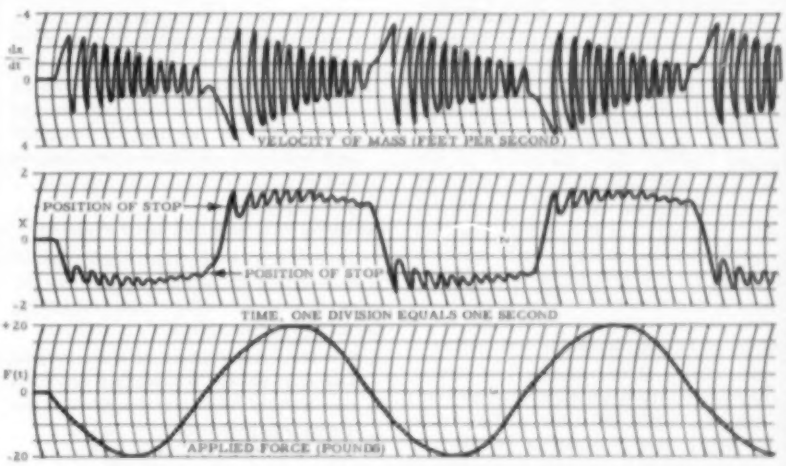


Fig. 6. Solution of spring-mass problem with stop restitution coefficient of 200.

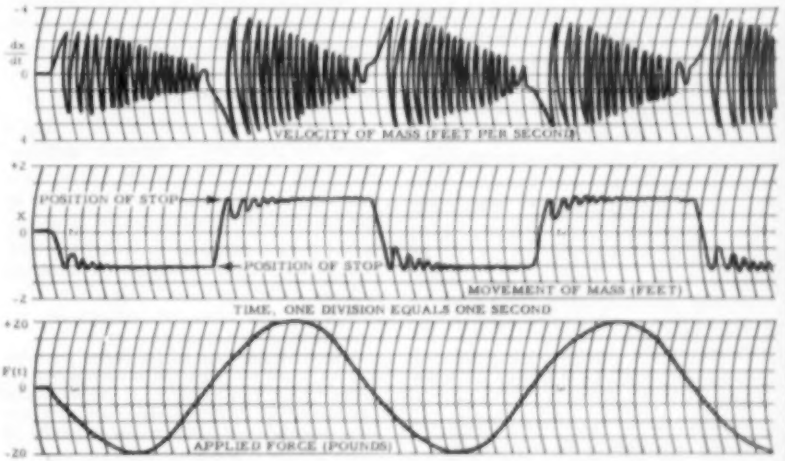


Fig. 7. Solution of spring-mass problem with stop restitution coefficient of 1,000.

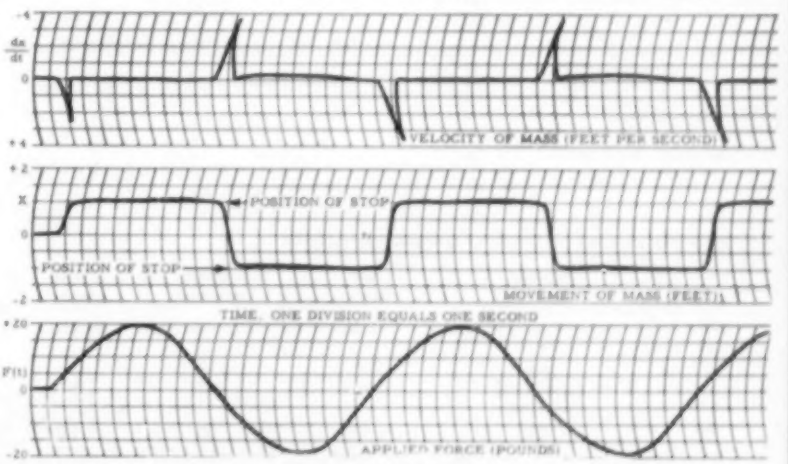


Fig. 8. Solution of spring-mass problem with an inelastic stop.

essential features of this scheme are to determine first the maximum expected magnitude of the problem variables. Then setting 1 v. on the computer equal to one unit of the problem variable, multiply each equation algebraically by such a constant as to produce the desired voltage level at the outputs of the computer amplifiers. Table 1 illustrates this procedure for the example used herein.

These factors are mentioned here to make the reader aware of some of the problems involved in adapting the computer to the simulation of a particular system. While the calculation of the time and amplitude factors is relatively simple the method involved and the required alteration of the system equation to accommodate them is left again to the texts *4B, 5B*, because of space limitations in this paper.

Choice of Analog Computer Installation

The choice of a computer installation is an extremely important one, and unfortunately must be made usually at a time when the responsible people are least able to evaluate their needs due to inexperience in the field.

No matter what size analog-computer installation is available, that installation, sooner or later, will be too small for some problems that will be encountered.

It is therefore imperative that there be provision to add on additional equipment to that originally purchased. Similarly, it should be kept in mind that error in an analog computer is accumulative; therefore, the highest degree of accuracy of components is to be desired.

Anyone contemplating purchase of analog equipment should investigate the following points:

1. Components should be of at least 0.1% precision.
2. Provisions for the use of multiplication and division equipment should be provided.
3. Equipment must be able to grow through purchase of additional equipment as problems and personnel experience expand.
4. Provisions for permanent recording of answers should be provided.
5. Arbitrary input function generators and provisions for determining special nonlinear functions of the pertinent variables are important for the solution of general problems.
6. If much work is contemplated, the use of the so-called "small scale computers" or specialized analogs of specific systems should be avoided by all means since their extreme specialization can only lead to disappointment later when other types of problems are met.

Personnel Required and Their Training

Experience with the operation of analog-computer installations has developed the following rules regarding necessary personnel:

1. A full-time maintenance man is necessary for each approximately 100 amplifiers or fraction thereof in the installation (equivalent to four average-size computers).
2. Approximately four full-time machine operators or programmers are necessary for each 100-amplifier installation if they do all problem planning and operation. A correspondingly smaller force is necessary if the engineers who originate the problems also develop the machine diagrams.

At present, the absence of a single reference book which tabulates and explains the operation of many of the computer circuits that have proven useful in the solution of problems makes it necessary for each engineer to devise his own circuits and thus duplicate the work of others.

A short bibliography on the digital computer may be found on page 454 accompanying the article "What You Should Know About Digital Computers," by F. H. Hollander and C. Tompkins, Department of Mathematics, University of California, Los Angeles.

Table 1.—Solution of a Typical Problem

B. The Computer Plan

1. Rearrange the equation

$$\frac{d^2x}{dt^2} = -\frac{D}{M}\frac{dx}{dt} - \frac{K(x)}{M}x - \frac{1}{M}G(x) + \frac{1}{M}F(t)$$

2. Determine expected magnitude of constants and variables

Variable	Expected maximum	How formed	Computer maximum	Scale factor
$\frac{dx}{dt}$	4	O.A.	4	1.0
x	1.5	O.A.	15	10
G	(1,000)(1.5) = 1,500	limiter	150	0.1
$F(t)$	20	function generator	20	1.0

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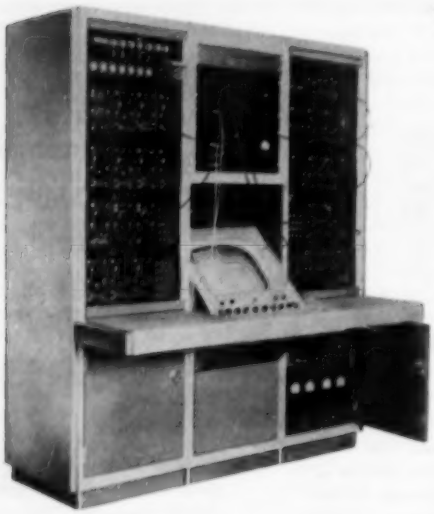
A·C·E·P·SPECIAL FEATURE



The Philbrick Analog Computer.
See page 450.

How can even a large chemical company justify the installation of a large digital computer, such as the Univac or one of the IBM 700 series, which involves a capital outlay in the neighborhood of $1,000,000? The answer is contained in this illuminating article which tells the story of du Pont's experience in the application of these giant machines to chemical process problems.

THE LARGE COMPUTER INSTALLATION

Arthur E. Hoerl

Engineering Service Division, Engineering Dept.
E. I. du Pont de Nemours and Co., Wilmington, Del.

Any technical computer installation must be built around two groups of key personnel: first, engineers who define the problems for study and, second, mathematical analysts who convert these problems into well-defined procedures which can be followed by the computing device. For chemical companies, the use of computers involves primarily chemical engineers whose problems range from distillation and reactor designs to statistical evaluation of past production data. Large-scale computers are fast, and therefore capable of processing a great number of different technical problems, each requiring a relatively long period of time for engineering formulation.

A large-scale computer is most profitable when being used to solve large-scale problems. Because of the inherent speed of these computers, even these large problems can usually be solved within a few hours; therefore, a large number of such problems are required to justify a large computer installation. In the chemical industry computer problems are, in the main, of the so-called "one shot" type, which are solved in a few computer runs. It is therefore necessary to have a potentially large pool of problem formulators before a computer can be considered.

Problem Formulators

These problem formulators are the research, development, and field engineers who weld together the mathematical-statistical techniques and the engineering problems. At present, a relatively low percentage of engineers has a sufficiently broad background in mathematical and statistical concepts and associated computational aids to think in terms of applying a combined approach to specific problems. Therefore, long-range plans must be specified, in conjunction with the computational installation, for a training and conditioning period to allow the engineers time to learn to think and plan in terms of the automatic computing aids. This seeming lack of know-how is partially a direct result of the type of thinking which has been required of engineers in the past; namely, because of physical limitations of slide rules and desk calculators, these engineers have been forced to think in terms of numerous approximations. Also, in studying and evaluating mechanisms simulated by mathematical models in the form of equations only, extremely limited ranges of the parameters and variables have been studied in detail with these manual aids. Long use of these manual methods of calculation has built up a way of thinking which only time and training can change. It will be some time before a sufficiently large group of engineers is available as a source of technical problems formulated for machine solution.

Mathematical Analysis

As the second part of the team, mathematical analysts are required; the function of this group includes programming and coding assistance to the engineers. In addition, this group sets up and formulates the broad types of generalized routines which serve as an integral part of any computational installation. Experience has shown that this group should be made up of mathematicians with a background in some field of engineering or physics since the proper engineering interpretation of problems is often required for their successful completion. On the other hand, due to the simultaneous mathematical aspects of these problems, they cannot always be resolved by the engineer alone unless he has a sufficient mathematical background.

Dual-Purpose Computer Use

As an alternative to the completely technical installation, a very satisfactory procedure is the simultaneous use of the large-scale computer for management

Data Processing

LARGE COMPUTERS

and for technical problems. Under these circumstances, for the larger companies these machines are justified for the routine processing of business data. This is a relatively easier justification because of the volume and the presently well-defined nature of the business calculations carried out within any company. In this case, since the problems already exist and no extensive training of personnel is required to convert these problems to computer language, immediate returns can be realized.

While original computational requirements in a company are often satisfied by a smaller computer, increasing difficulty is likely to be experienced in attempting to solve efficiently the larger problems which are sure to be formulated. Ultimate justification of a larger computer is provided when engineering problems have expanded to such a degree that they can no longer be solved conveniently without greater computer speed and storage capacity.

Types of Equipment

There are available at present many different types of large-scale computers. Some of these have been designed for efficient operation in the processing of business data; others have been slanted toward technical problems. Basically, there are three major specifications of any computing device which fairly well fix its purchase price, and vary widely between computers:

1. Input and output devices.
2. Internal storage capacity.
3. Speed of operation.

For business problems the accent is on Item 1, input and output, with an additional stipulation as to self-checking features. Technical problems require a stronger accent on Items 2 and 3, storage and speed. This is so because business problems entail large volumes of data and limited computations. Conversely, technical problems usually include a small volume of data but a very large amount of computation. It is not unusual to find a technical problem, defined with only hundreds of numbers as input and output, which requires millions of multiplications and additions for its solution.

The tremendous capabilities of these large-scale machines can be appreciated when it is considered that information can be read in and out at the rate of from 600 to 2,400 words per second (a word usually consists of 8 to 12 numerical or alphabetic characters). Within the computer itself, these words can then be compared, multiplied, or added, at speeds of thousands to tens of thousands per second.

During the past two years the du Pont Company has been using a Univac computer to explore areas of the company's work in which profitable application of a large-scale digital computer can be made. Both business and technical areas of work are being investigated. This discussion deals only with technical computations.

In addition to the Univac, du Pont has available other *moderate-scale* computing devices which include a Philbrick Analog, several IBM Card-Programmed Calculators and 650's, a Readix, and a Bendix computer. In certain instances, one or another of these smaller computers has been used in conjunction with the Univac in the solution of a given problem.

Manpower

Selection and training of a competent programming staff has been the most important factor in du Pont's computational effort. There is one technical programming group of sixteen men working full time with the computer installation. This group works on a contract basis in programming, that is, formulating and solving on the computer specific problems for other groups in the company.

Within this technical computations group, three broad categories of personnel are utilized. These are:

1. Mathematical and statistical analysts.
2. Coders.
3. Utility assistants.

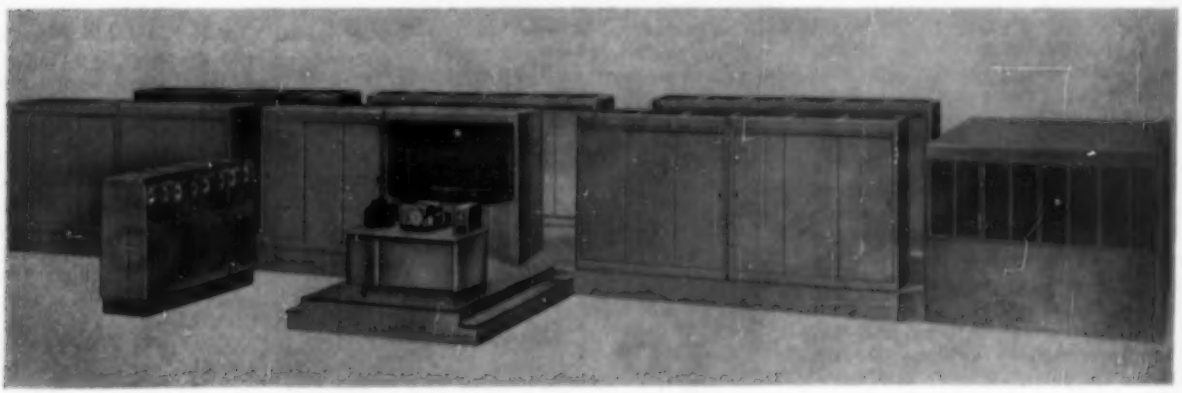
The first of these are the highly trained mathematicians and statisticians who assist the engineer in the formulation of specific and general types of problems. They also lay out the procedure to be followed for the numerical calculations. The coders, in turn, rewrite this procedure into machine language and follow through the complete solution of the problem on the computer. The utility assistants, primarily high school graduates, prepare tabular input data and proofread the prepared tapes. In addition, they carry out any desk computations required for checking purposes.

In addition to the central group, approximately 150 du Pont engineers have been given from two to six weeks of intensive machine coding instruction. These engineers represent a reasonable cross-section of the company and, while they continue to work primarily in their own engineering fields, many devote part time to programming specific engineering problems.

Computational Examples

Prior to the advent of high-speed computing devices, engineers were restricted essentially to three approaches in the study of process mechanisms:

The Univac Scientific Computer. Particularly suited to large-scale scientific calculations—large input, small output. Regular Univac suited for highly repetitive tasks—small input, large output (see page 450).



1. **Rule-of-thumb approximations, or a limited exploration of mathematical equations which describe the process mechanism.**
2. **Pilot plant simulation of a process mechanism.**
3. **Trial-and-error changes in operation of a process mechanism.**

The advent of high-speed computing devices now permits supplementation of the aforementioned approaches with an additional extended means of process exploration to obtain higher efficiencies and production. First, it is now possible to extend the mathematical formulation and exploration of process mechanisms which are expressible as mathematical equations. Second, it is possible to examine and analyze large volumes of production data to evaluate quantitatively the interrelationships of the process variables to production, quality, or to any other characteristic of interest.

EXAMPLE 1

Less than two hours of Univac computation served as the basis for the elimination of a costly plate column from a new plant design. In the preliminary specifications, which included a chemical reaction and absorption, the design called for a packed column to cool the gas and a plate column to absorb the gas. However, one of the engineers suspected that the packed column might be absorbent enough to eliminate the plate column. On this basis he set up the equations and submitted them for Univac computation. The results of this analysis substantiated his conclusions and served as the basis for a change in design. Because of the design schedule of this project, it is entirely possible that this mathematical analysis might not have been undertaken with a slide rule or desk calculator.

EXAMPLE 2

There has just been completed on the Univac at du Pont an analysis of production data for a process which has been in operation for over twenty-five years. Because of the inherent variability and interpretive complexity of this batch process, over 400,000 separate runs made during the past few years were required for a statistical evaluation. In addition, each of these runs included approximately ten separate pieces of information. The goal of this analysis is an improved operation and scheduling procedure involving several hundred thousand dollars in increased efficiency. The results could not have been obtained otherwise than by a systematic analysis of this large volume of data and this volume could only have been processed by a high-speed electronic computer.

EXAMPLE 3

A third example involves a particular reactor which has been in operation for about five years at one of the company plants. Wide ranges in operation and daily variations in production had been observed during this period. One of the process engineers thought that he might be able to relate them by a cause-and-effect analysis. A few preliminary graphical plots of some of the log data soon indicated that this approach would yield substantially no information because many process variables had affected production simultaneously. The graphical approach by necessity had restricted them to two at a time. If it had been feasible, plotting in eighteen dimensions would have obviated this difficulty.

At about this time, information concerning the new computer installation was received by the plant under discussion. This led to a preliminary meeting between statisticians associated with the computer and the plant engineer. During initial discussion periods, attended by production, technical, and research personnel, the process flow diagram was outlined and the problem defined in its broadest aspects. It was immediately concluded that the application of a statistical technique called *multiple regression analysis* would answer the questions raised by the plant.

With this technique an empirical equation containing at least as many terms as there are variables is assumed. An example of the simplest form of an equation of this type is $Y = a + bT$, where T is temperature and Y a yield. The equation is then fitted to the available data by the so-called *method of least squares*. That is, the distances between the observed points and the theoretical line are successively squared and added. The specific values of a and b which make this sum a minimum is the solution to the problem. (See Figure 1.)

During subsequent meetings with plant personnel, seventeen variables were selected as the basis for an empirical representation of the process. For this part of the analysis, the team approach of engineer plus statistician helped considerably in arriving at a suitable definition and basis for study. For example, there had been some question as to how to express the activity of the catalyst bed since no direct measure was available. The statistician derived a functional relationship based on average catalyst age. This then served as a measure of the bed activity.

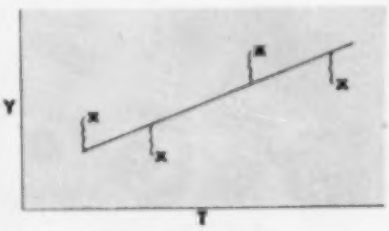


Fig. 1. Method of least squares.

As the next step, approximately three weeks were spent by the statistician in peripheral analysis on the CPC (IBM Card-Programmed Calculator). The smaller machine was utilized because of the trial-and-error type of analysis which required direct contact with the computer.

An additional meeting was then held with plant personnel to discuss these results and to select the final form of the regression equation. The major contributing factor in the selection of this equation was the engineering insight contributed by plant personnel. The equation itself in its initial form included the seventeen independent variables expressed in selected combinations of fifty terms.

The next phase of the study included the Univac computations required for determination of the unknown coefficients and for the statistical interpretation of the results. Because of the high reliability of these results, many additional machine analyses were also carried out. In all, approximately four months were required to follow through the fifty million arithmetic operations necessitated by this study.

These results were then reported to plant personnel in the form of predicted performance curves for all of the important process variables. These curves were to serve as the basis for making future operating changes to improve ultimate production. As an initial evaluation, one major change was made in process operation; preliminary results indicate a substantial improvement in production. However, to evaluate all of the results fully, a two-year planned program has been set up. During this period, successive predicted changes will be made and evaluated in relation to the derived equation. Modifications in the equation will be made if required.

Summary

This paper has outlined some of the various approaches which are being used at duPont to solve engineering problems. The gains that have been realized through the use of these approaches have resulted in significant returns. Even though we are still only on the threshold of the potential returns that exist in engineering mathematical analysis, it can be stated that many of these gains have resulted directly from the recent availability of high-speed computing devices, without which most of these and similar analyses would never have been attempted.

Presented at A.I.Ch.E. meeting, Los Angeles, California.

At the round table discussion in the UCLA amphitheater are (l. to r.): T. J. Williams, U.S.A.F. (now with Monsanto); C. B. Tompkins and F. M. Hollander, UCLA; moderator Curtis Johnson, Washington University; Archer Opler, Dow Chemical Co.; and A. E. Hoerl, Du Pont.

BY 1963

COMPUTERS MAY BE RUNNING PLANTS

This and other points were brought out by the authors of the preceding papers, who participated in a Los Angeles round table discussion (February National Meeting, A.I.Ch.E.) on how a chemical engineering process firm gets started with a computer program.

R. C. Johnson: In opening this discussion, we might tackle the question as to whether you as people of wide experience in the use of computers feel that in the very near future a computing installation is going to become an essential part of every chemical plant.

Hoerl: There certainly has been a strong movement toward digital methods of plant data recording. I expect that by 1963 or 1964 we may know enough about computers to allow them to run a plant. I'm speaking now of full-scale plants and not of laboratory or engineering groups.

R. C. Johnson: Do you feel therefore that every research group should have a computer or access to one?

Hoerl: Under existing economic conditions, with rising costs and increased salaries, I believe that in the future it will be necessary to get as much as possible out of process equipment performance. I think that the engineer's know-how has been used to the utmost up to the present time. What is needed now is more theoretical study of the mathematical aspects of the problem in order to get the additional 5 or 10% which might be possible from increased production. For that reason, I think that, in the long range picture, virtually all process companies will need these computers to attain the required further process improvements.

Tompkins: One factor which encourages companies to acquire computers is that the cost of a computer can sometimes be shared between engineering and accounting departments. In addition, there is a third class of computer use which is assuming increasing importance in many companies. This has to do with the management-type problem. This includes the programming of the order in which operations will be carried out. Business management is becoming more aware that this type of computer-aided calculation can be of great help in decision making.

Williams: The petroleum and chemical industries are now tending toward control by analysis. If we're going to use mass spectrographic data for control, the computations must be made very quickly. The only method fast enough is the use of computers, probably digital. To actually control the plant some sort of analog element will have to be added.

INSTALLATION JUSTIFICATION

R. C. Johnson: The next question is—how are we going to get started; how are we going to convince management that we are really going to save money and thus justify the installation of a computer? This seems to be a very real problem to the industrial men with whom I have been talking.

Hoerl: Our experience at Du Pont has been that you justify the installation by making an evaluation of the potential gains available through the use of computational techniques in the solution of engineering problems. One gets over the initial hurdle by convincing management to accept the system on a trial basis.

R. C. Johnson: What is the proper place in a plant or company for a computer group? To whom should they be responsible?

Hoerl: From our experience at Du Pont, the most likely place seems to be in the engineering department—within a group that does consulting work with the company as a whole. In Du Pont, there are ten industrial departments and fourteen auxiliary departments. The engineering department is an auxiliary department which does not manufacture anything and sells nothing except services to the other industrial and auxiliary departments. This seems to be an excellent place to install an activity of this type because of the many contacts which already exist between engineering and the other departments. It is necessary for the computing group to go out to these people to show them what can be done with the aid of computing devices.

Opler: While computing groups may start as adjuncts to engineering, accounting, or research departments, the goal should be an autonomous group with freedom to move anywhere that is required, throughout the company. This is a goal—not a demand that you will get at first.

However, if you will extrapolate the present progress of computing in practical industrial work ahead a few years, I think you will see that computing will become of sufficient importance to all departments of the company to cut across all lines and become an independent department.

Williams: We at Wright Field have found that a computing organization must be as autonomous as possible. We realize that direction is necessary, but we wish to avoid having one small group monopolize the service.

Tompkins: It seems to me that the users of the machine should be scattered throughout the existing departments. What is needed is free and convenient access to the machine for every operating department. In each department there should be a core of people who understand the problems of that department and how to get these problems on to the computer.

At the Univ. of Calif. we're so organized that we can let anybody play

with our machine and not worry about losing money. So we have, indeed, done this and have done it quite successfully. Our machine holds several records—of an academic nature if you like. One of the more spectacular was the analysis of the crystal structure of vitamin B-12, which is probably the largest crystal ever analyzed in this way from X-ray diffraction data. The members of our department of chemistry who did this analysis were initially rather appalled by the notion that they would have to learn to run the machine. However, they finally applied the machine with the greatest known efficiency to their particular chemistry problem—with an efficiency which, I am certain, my machine group could never have matched had the problem been farmed out to us from the outside. I believe that this method might also be the best one for commercial firms.

Opler: Prof. Tompkins has just opened a sort of Pandora's box. One of the most controversial problems in computing circles now is the open vs. the closed shop. A large number of installations practice the closed shop. There the rule is this: If you are an engineer with a problem, come in and talk to our mathematical analyst. He will decide whether your problem is suitable for the machine. If it is, you stay at the door while he takes the problem and works on it. He then comes back and says—"Is this a good analysis?" If you say "yes," he then turns it over to a programmer or coder. The problem is then coded, tested and run. Next, they come back to you, the engineer, with the results and say, "Is this the right answer?" You say, "yes, or no." This goes on until satisfaction is obtained. This is the closed shop principle. There are a number of arguments in its favor. All the people in the computing department know exactly what they are doing, they are well trained, they push the right buttons, they don't make many mistakes.

The other approach is the open shop principle. The people around the computer are helpers. You come in with your problem and they will show you around the installation and will give you a book of coding forms. They spend a lot of time in the various departments teaching, preparing manuals and specific routines which make it simple to run the machine. I am frankly prejudiced. I favor the open shop and I can think of several cases where it has worked amazingly well. Probably the most spectacular has been at Los Alamos. Here they have a tremendous staff of high-level physicists, chemists, and engineers but, while they have good mathematicians, there is a very small computing staff. What is true of Los Alamos is also true of Livermore, Oak Ridge and other atomic installations. They have trained their people so that more problems can be put on the machine. People on the staff are more responsive to what the computer can do. They are conditioned to computers and the idea of using them has spread throughout the organization.

To me personally the idea of a closed shop is not inviting and I do not think that it will stimulate creative engineering.

R. C. Johnson: Mr. Ray Smith of Carbide and Carbon has asked if we feel that the specialized knowledge that the engineer may have of his particular problem offsets the training of the computer mathematician?

LEARNING THE "MYSTERIES"

Opler: I believe that a practicing graduate engineer is in a good position to pick up computing. Computing is simpler than it is made out to be, whether it is a question of wiring a 602-A or programming a 701. There has been an entirely unnecessary aura of mystery about this. Here is a rule of thumb which I use when I tear the result sheet off the computer's printer. I ask myself three questions:

1. Are the results obtained consistent with the program that was written?
2. Are they consistent with the mathematical formulation of what the program was supposed to do?
3. Are they consistent with the common sense experience that the engineer had when he put in the problem in the first place? Does a distillation column behave like this? Do we expect heat transfer to behave in this manner? Is this the sort of flash equilibrium that we expect?

All three questions are needed and only all three will give you the right answer. This takes an engineer, a mathematician and a computer specialist working as a team.

Tompkins: Our experience with an open shop, which developed from a closed shop at the Univ. of Calif., has been most gratifying. The general trend seems to be toward the open shop. In the recent recommendation of the American Society of Engineering Education with regard to mathematical curricula for engineering students presented to the Ann Arbor conference last June, there were suggestions that all mathematics courses offered to engineering students be revamped in the light of the present importance of numerical analysis and that, for instance, when you study differential equations, you actually present the numerical solution of the differential equation as a strong part of the course. I gave a beginning course in differential equations last semester in which the first thing I did was to point out that the students knew how to solve differential equations approximately by simple forward differences. We solved a few; on the first day, for instance, we took the last problem in the book and the students found that they could solve it all right. This approach seemed to be helpful in understanding the course and it may tend to alleviate the situation where the engineer will not know enough about numerical analysis and machines to be able to function efficiently.

Williams: I wonder whether the optimum use of manpower would not perhaps be a combination of the open and closed shops. I am thinking again of the Wright Field analog installation. There, people from all over the country bring in their problems. These are aircraft problems, missile problems, and many other types. These problems—the actual equations which must be solved—are given to the people who can use the machines. In order to make optimum use of a machine, you need somebody that knows a lot about it. A man who has had much experience on the

The amphitheater session permitted attendance at the round table discussion by a number of interested chemical engineers.

machine is better fitted to do this than most engineers who have problems they want solved. However, when it comes to getting the answer, the man who wired the machine doesn't always understand the problem. The engineer who has been thinking about the problem does understand. At Wright Field, when they get around to actually solving the problem, the engineer is present. He actually watches the answers come off the machine and can tell the machine operator whether they are right or wrong. In this way, we get the most answers in the least possible time and the most efficient use of both our manpower and our machine.

WHICH EQUIPMENT?

R. C. Johnson: Mr. Ludka of M.M.M. has brought up this question: His company is planning to acquire a large digital computer. They still have an IBM 604 and perhaps some intermediate equipment. Should this company be interested in some analog equipment also? I would like to add another question. Is it a good idea for a company, which has a large machine of the 700 series or Univac size, to keep one of the smaller digital machines? Under what conditions might you keep the smaller as well as the larger machine, and under what conditions might you be interested in having analog equipment also?

Williams: If you have something like a 704 or a 705, I would say that use for analog equipment would only arise if you are interested in automatic control work. With certain types of ordinary differential equations, the problem is better solved on analog type equipment than on even the 700 series, since you need so many answers so fast. If you don't have this type of problem, don't buy analog equipment since almost any other problems you may have can be done better on your other equipment. For instance, algebraic equations are better solved by other machines and partial differential equations are better solved on digital machines.

Tompkins: It seems to me that this is merely a matter of economy. Up to date, the larger machines have furnished multiplications at a lower price per multiplication than any smaller machine. We have sent all our smaller machines back to pasture and simply program SWAC to act like a CPC and to use old CPC codes. We just could not afford to keep the smaller machines—they would have cost us too much per multiplication.

Opler: Frankly, I think that Mr. Ludka is going to find himself in a very unhappy position.

There are six large commercial machines available: 701, 702, 704, 705, ERA 1103 (sometimes called Univac Scientific) and Univac. These fall sharply into two different classes. Although the 702 and the 705 are quite similar, there is a world of difference between the 701, the 704, the Univac and the ERA 1103. The 702, 705 and the Univac are, at best, only moderately good for engineering computing. The 701, 704 and the ERA 1103 are superb for engineering computing. This company is going to have a business type machine which is rather poor for engineering computing. Actually, it will be only somewhat faster than the 650 and not any easier to program. It is going to have a 604, which is a small computer, and a large computer which is not well adapted to engineering calculations.

R. C. Johnson: The company involved says that it was their accounting department which got the machine.

* SWAC—Standards Western Automatic Computer. Built by U. S. Bureau of Standards, now owned by UCLA.

At another moment in the discussion (l. to r.): C. B. Tompkins, E. M. Hollander, Curtis Johnson, Archer Opler, and A. E. Hoerl.

Opler: That is doubly unfortunate.

Hoerl: As we progressed from desk calculators to an analog computer to a CPC to a Univac, we found that we had twice as many desk calculators and twice as much need for additional CPCs. I think this is because you just can't afford to have engineers play with a $300 per hour machine. Even when we are working particularly difficult and complicated problems with the Univac, we take time off and run them on the CPC to get a feel for them. It's much easier to change an iteration on a CPC, since it only involves punching and repunching a few cards, than it is to try to change instructions in the Univac. We have also found that being able to work with the machine and being in direct communication with it, you do build up more of a feeling for problems than you do with the larger machine where all you see is a lot of blinking lights. So, the further we get into this field the greater need we find for the smaller computers.

Hollander: At U.C.L.A. we have found that the smaller computer can always be simulated by the larger one. Also, contrary to Dr. Hoerl's experience, we have found that it is much more difficult to change a straight line type of communication than it is to give the computer some kind of an iterative system and to modify this by a tally command to get what you want. In other words, in working with the large computer, one should aim at creating the logical system to begin with, in order to encompass all possible changes. This will make it simpler to change the routine in the big computer than it would be in a CPC or other type of small computer. I myself have struggled with 604 boards, asking the machine to do something a little different, and I feel that I'd much rather sit down and modify the computer command on SWAC.

ANALOG OR DIGITAL?

Tompkins: The alleged difficulty in changing parameters on large digital machines, both with respect to the solution of differential equations and other problems, has been exaggerated. Normally, with the large digital machine, you don't change the parameter—the machine does it. If you have a systematic scheme for going through these parameters, even a devious one, you

normally code the change of parameters into the problem itself and the machine goes ahead and changes its own parameters. I claim that this is even easier than turning a knob.

I might as well use my punch line and open up the warfare here. I am not at all convinced that the analog machine is faster or more accurate even on these ordinary differential equation problems. It has a major advantage, that of cost; other than that, if you have a digital machine, I do not think that it is more difficult to change parameters or to make minor changes in the program. By and large, you usually have the machine make these changes for you.

Williams: In automatic control, you are really interested in knowing whether the system is stable or not and, if it is stable, what sort of error you are getting. You also wish to know the magnitude of the actual steady-state error in your process. The analog computer, by pointing out the actual answer you are obtaining as the problem is being solved, tells you immediately whether the system is stable or not and the error. I don't see how the digital machine could be simpler than that.

Hollander: At least as far as the SWAC is concerned, I think that the digital machine is going to steal your thunder. We are about to install in this machine an oscilloscope which will trace out point by point any curve which is to be computed. I think that in this case we've really merely attached something analog to the digital computer and that we now have the advantage of the digital computer plus the advantages of whatever your analog facilities provide in the way of visible output.

Williams: While analog machines are cheaper they are also much smaller. So, especially with the complex, automatic control process, you can quickly run out of space. For instance, we recently did a problem on the automatic control of a distillation column. We have a hundred-amplifier machine, which is a very large analog installation. Nevertheless, we were limited to five plates. On your digital machine, of course, this is not generally so. If the digital machine can be programmed to make the proper changes in the control variables, that is, if it can add the proper amount of integral control, proportional control, etc., then, of course, there is no need for analog computers. The main reason for the analog computer is this: when the operator knows from experience that the process is acting in a certain way, he can add more integral control or more derivative control by changing one of the knobs. I think that this would be very difficult to do on the digital computer by initial programming because in most of these cases you don't know in advance which way the system is going to act.

Hollander: I believe that this would be difficult but I wouldn't say that it was impossible. If you did this you would have a general solution for your system. This solution would be all-encompassing and would be useful from then on if it's a one-shot code.

R. C. Johnson: In talking to representatives of companies which have large computing facilities available, but at widely scattered points, I find one group which, for two or three reasons, is interested in putting in an analog installation. One reason is that they believe that they can filter out some of the problems without having to put them on the larger digital machine. Another reason is that they think that they can do a great deal in educating their engineers at quite a small expense. With a moderate investment, they expect to arouse a lot of interest in computation in general, both analog and digital.

Also, it is possible to increase the size of an analog unit in jumps of $20 or $30 if it becomes necessary to add one more amplifier.

Williams: Actually, commercial analog computers of sufficient accuracy to be really worthwhile normally come in units of about twenty amplifiers. These twenty-amplifier units will, at the moment, cost you anywhere in the order of $5,000 to $20,000 each, for pre-built machines. You cannot normally buy one amplifier and hook it on. This, of course, does not apply to the Philbrick type of installation. However, while the Philbrick installation is good for proving calculation methods, its accuracy is only about 5%. The machines referred to before will give you 1% accuracy.

To return to the previous question, while an analog installation will of course generate lots of interest, knowing how to program an analog machine will not tell you how to program a digital machine because they are entirely different beasts.

ANALOG PLUS DIGITAL

Opler: I think that there has been some confusion about program correction. Art Hoerl was talking about doing this on a CPC. There, you simply insert one or two cards if the program isn't coming out right. On many larger machines it's quite easy to insert a new instruction from the control console. Sometimes this is a little expensive, but it can be done.

The fact is that there is not much conflict between analog and digital computers and, if there is, it is going to be eliminated by some sort of shot-gun wedding. In the first place, digital computers are being equipped with analog output devices. I have seen digital computers that plot graphs directly. I have seen results plotted on the face of an oscilloscope. Other digital computers punch paper tapes and cards which may be fed into plotters so the results can be recorded graphically.

On the other hand, devices are already being used in which curves are being followed automatically and converted into digits. This is "digitizing." They are then fed into a digital computer as a forcing function. So, the gap is gradually being closed.

At one computer installation in this city they have a large digital computer. In the next room they have a large analog computer. These are in adjacent rooms for one purpose; they plan to hook them together in the very near future. This interconnection has been built into the digital machine and is being built into the analog computer. The analog computer will compute for a while, then the digital will take over, and the ultimate results will then be plotted on the analog computer.

There is one feature of an analog computer that I really appreciate. This is known as "dial twiddling." You sit at the controls and, after you reach a solution, you say to yourself, "I wonder what would happen if 10% went through there? I wonder what would happen if I fed it through at twice the flow rate? I wonder what would happen if the viscosity dropped?" That is one very nice feature of analog computers.

Now it turns out that this is the very latest thing in digital computers. At a recent digital computing meeting there was a talk on the topic of "Gestalt Programming." The basis here is that the best combination is not two engineers, it's not two computing machines, but it's the engineer (or the scientist) and the computing machine working together. The principle of Gestalt Programming is the pooling of their resources. The computing machine does what it can do best, and the human does what he can do best. The computer is programmed in such a way that it easily accepts information in the form in which the human can put it in; the program leans over a little bit to the human side. This is perfectly feasible in programming a computer. This is the future trend. I think that, eventually, between analog, digital, and human, we'll have the loop well closed.

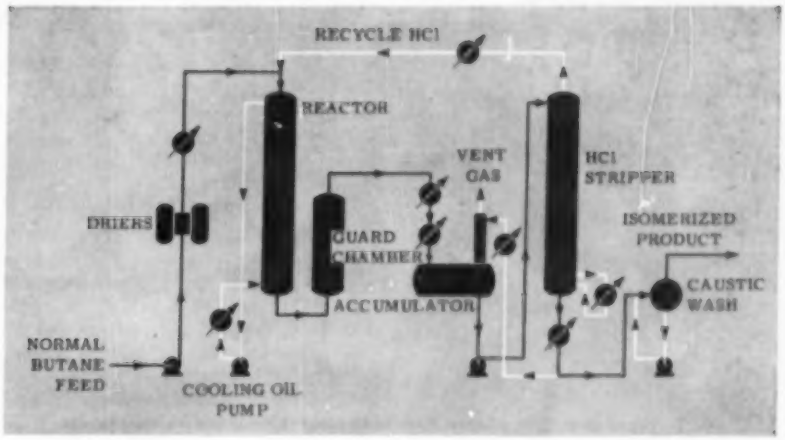


Fig. 1. Flow diagram of Shell isothermal vapor-phase butane isomerization process.

How do large chemical companies use preliminary estimates during the development period of a new process? Here is an illustrated case history from the files of the Shell Development Company. According to the authors, the relation between costs of initial laboratory studies, process development studies, and pilot plant studies is of the order of 1 to 10 to 100.

COST ESTIMATION in the development of a new process

J. A. Samaniego and C. R. Nelson | Shell Development Company, Emeryville, California

In process evaluation work, several types of estimate are generally used. When a process is in a speculative stage, supported perhaps by a single experiment or by some "reasonable" but yet unproved assumptions, a *screening cost estimate* is prepared. As soon as enough additional laboratory data are available to enable the chemical engineer to confirm or modify the hypothetical process design used for the screening estimate, *a preliminary cost estimate* based on the modified process flow is made. The next step is the *process cost estimate* which follows when all major process questions have been answered and the practicality of the process has been established. Finally, if a process is approved for construction, a *plant estimate* is made. This is based on a final engineering design which includes specifications for every piece of equipment down to the valves and fittings.

Case History

The entire procedure can be illustrated by using as an example the Shell Liquid-Phase Butane Isomerization Process. At the time research on the process was undertaken, Shell had already developed and used commercially an isothermal vapor-phase process for isomerizing normal butane. The venture, therefore, was not so much to develop a new process in an absolute sense, but to invent and develop a process superior to an existing one for making a product of established value.

VAPOR-PHASE PROCESS

Figure 1 shows the Shell isothermal vapor-phase process schematically. After drying, the normal butane feed is vaporized and is charged together with the HCl recycle stream to an isothermal reactor, which consists of multiple units. Normal butane is isomerized in the presence of bauxite impregnated with aluminum chloride. The reactor effluent passes through a guard chamber which is filled with bauxite, the object being to remove any aluminum chloride which may be carried out of the reactor. The raw product is then condensed and cooled. The condensate is collected in an accumulator from which a small amount of light ends is vented through a small packed absorber; stripped isomerizate is used as absorbent. The liquid reactor product is then stripped of HCl in the HCl stripper. The top product is recycled to the reactor and the stripped isomerizate bottom product is cooled, caustic washed, and pumped to storage.

LIQUID-PHASE PROCESS

After establishing that liquid normal butane could be isomerized to isobutane in the presence of a solution of aluminum chloride in antimony trichloride, the inventors set forth the basic process principles. Figure 2 shows schematically their conception of the liquid-phase process. The processing of the raw isomerizate was already well established from experience with the vapor-phase process. Although it was evident that the isomerization reaction in the liquid-phase process could be carried out at a substantially lower temperature than in the vapor-phase process, and hence that the formation of light ends might be eliminated, it was decided conservatively to use the same raw isomerizate handling scheme which is used in the vapor-phase process. In both processes the feed needs to be thoroughly dried. In the vapor-phase process, the dried feed is completely vaporized before entering the reactor. In the liquid-phase

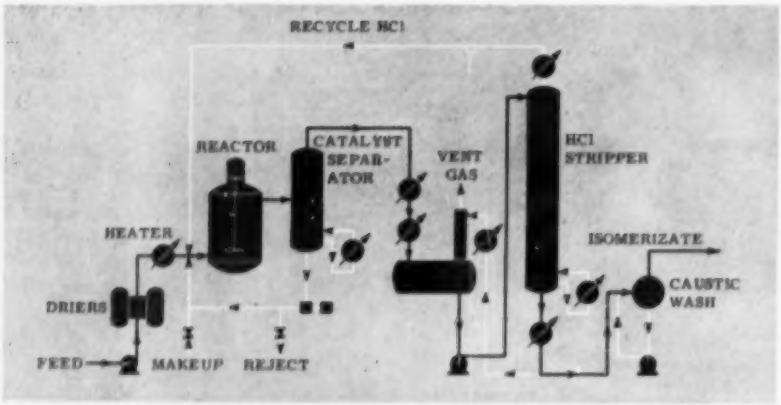


Fig. 2. Hypothetical flow scheme, Shell liquid-phase butane isomerization process.

process, it is heated to reaction temperature and, after leaving the reactor, it also is vaporized to separate isomerizate from catalyst. Essentially, then, the two processes differ mainly in the reactor section. (The two reaction sections are shown separately from the rest of the process in Figure 3). In this case, the screening cost estimate showed the liquid-phase process to have capital and operating costs about 60% of those of the established vapor-phase process. This resulted mainly from the indicated higher conversion per pass, much simpler catalyst handling facilities, and generally smaller physical size of equipment for a given isobutane capacity. Table 1 outlines the items involved in the cost estimates. Capital requirements comprise the cost of the process unit completely installed, that is, ready to operate; utilities, which include a share of the cost of steam, cooling water, electrical system, compressed air, and other facilities in the refinery or chemical plant; and offsites, which include a share of the cost of other items such as offices, shops, warehouse, change rooms, cafeteria, roads, etc. Operating cost covers utilities which include the cost of steam, cooling water, electric power, compressed air, etc., which are actually consumed by the process; chemicals and catalysts, which include the cost of such materials used in the treatment of feed and product and in carrying out the reactions involved in the process; operation, which includes operating labor, supervision, and materials; maintenance, which covers the cost of labor and materials for maintaining the plant in operation and repair; overhead, which covers plant and head office management costs, including insurance and taxes; and royalties if it is necessary to operate under existing patents of others. All the cost estimates made at the various stages in the development of a process follow this general pattern. Based on the data on hand, they are all made with the same degree of care. Differences among them will be due to differences in the corresponding designs rather than to the use of different estimating techniques.

MODIFICATIONS

It soon became evident that the process could not quite be carried out according to the hypothetical flow scheme shown in Figure 2. For example, it was found that the separation of isomerizate and catalyst leaving the reactor could not be effected by a simple flash. Even though there is a very large vapor pressure difference between the isomerizate and antimony trichloride, it was found that it would be necessary to provide a few trays and reflux to effect a complete separation of these two components. Even traces of antimony trichloride in the isomerizate would cause difficulties in the equipment downstream from the catalyst column. It was found also that the catalyst lost activity due to accumulation of a hydrocarbon-aluminum chloride complex and a practical means for maintaining high catalyst activity had to be provided. Catalyst makeup would, therefore, be required not only to compensate for mechanical losses of catalyst, but also to compensate for chemical deterioration of the catalyst itself. At that stage of the development program, the optimum reaction conditions, such as temperature, pressure, and hydrocarbon/catalyst phase ratio, had been firmly established. It was then possible to draw up a practicable process scheme which served as a basis for the preliminary cost estimate.

Table 1.—Cost Estimate

A. Capital Requirements	
Process unit installed	
Utilities	
Offsite facilities	
B. Operating Cost	
Utilities	
Chemicals and catalysts	
Operation	
Maintenance	
Overhead	
Royalties	

Table 2.—Process Cost Estimate

Shell Liquid-Phase n-Butane Isomerization
Capacity: 1,000 bbl./day isobutane

	Cost relative to vapor-phase process
Capital	0.69
Operating	0.73

Table 3.—Present Cost Comparison

Butane Isomerization 1,000 bbl./day isobutane

	Vapor-phase process	Liquid-phase process
A. Capital requirements	$1,475,000	$1,375,000
B. Operating cost, ¢/bbl. net iC_4		
1. Utilities	9.10	7.61
2. Chemicals and catalysts	8.67	8.98
3. Operation	22.17	20.57
4. Maintenance	8.37	10.13
5. Overhead, insurance, taxes	36.41	34.43
6. Royalties	.....	.....
Total, ¢/bbl.	84.72	81.72

PILOT PLANT STAGE

Since the apparently workable process scheme did not differ radically from the hypothetical flow scheme, the preliminary cost estimate continued to show substantial cost advantages for the liquid-phase process over the vapor-phase process. With no change in the other

considerations* and with the additional finding that normal pentane could be isomerized to isopentane in the same equipment with but minor alteration, a pilot plant program was undertaken.

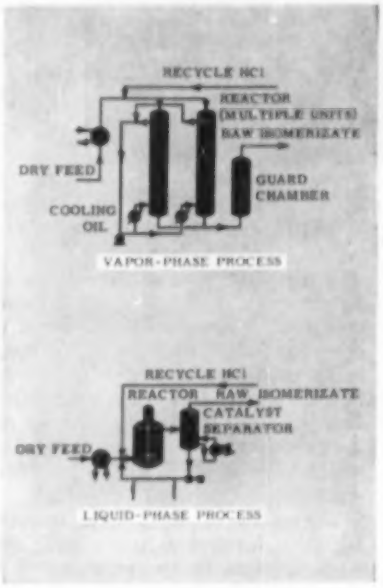
Some months later, it was established that it would be too expensive to maintain catalyst activity by the simple expedient of continuously bleeding off catalyst and continuously adding a corresponding amount of fresh catalyst. This problem was satisfactorily solved by providing a reject catalyst scrubber, in which the active ingredients—aluminum chloride and antimony trichloride—would be extracted by the incoming hot butane feed. Only the insoluble aluminum chloride-hydrocarbon complex would be left to be rejected from the bottom of the scrubber. Continuous operation in the pilot plant also gave very valuable information about materials of construction and performance of equipment. It was then possible to design a practical plant. Figure 4 shows the finished version of the process. This flow diagram, with all the process information which had been established as optimum by the pilot plant runs, formed the basis for the process cost estimate.

COST SUMMARY

Table 2 summarizes the results of the process cost estimate. Besides this favorable relative cost picture for the liquid-phase process, there was also in its favor the consideration that the process could be readily adapted to isomerize normal pentane to isopentane, for which there was a military demand. Finally, the process was approved for construction, and by the end of World War II four liquid-phase plants were operating; since then two others have been built. The results of commercial operation confirmed the estimated advantages of the liquid-phase process over the isothermal vapor-phase process. However, to be faithful to history, it must be added that the vapor-phase process has been improved significantly on two counts: first, it was found possible to operate the reactor adiabatically, and second, means were developed for making the catalyst in the reactor itself by subliming aluminum chloride onto the carrier. These improvements substantially reduced capital cost through elimination of a catalyst plant and the reactor cooling system, and reduced operating costs mainly by increasing catalyst life. At present, therefore, the difference in capital and operating costs between the improved adiabatic vapor-phase process and the liquid-phase process has narrowed. Table 3 shows how the two processes now compare. These figures are based on actual commercial plant experience with the processes. The liquid-phase process still has the inherent advantages of greater tolerance for feed impurities (olefins, sulfur, C_5^+), higher and constant conversion per pass, and ready adaptability to pentane isomerization. The second of these is reflected in the slightly lower capital and operating costs.

How the processes will compare in the future will depend on the creativeness of our scientists and engineers. But whatever improvements they may propose, one can be sure that cost estimates will play a major role in their development and reduction to practice.

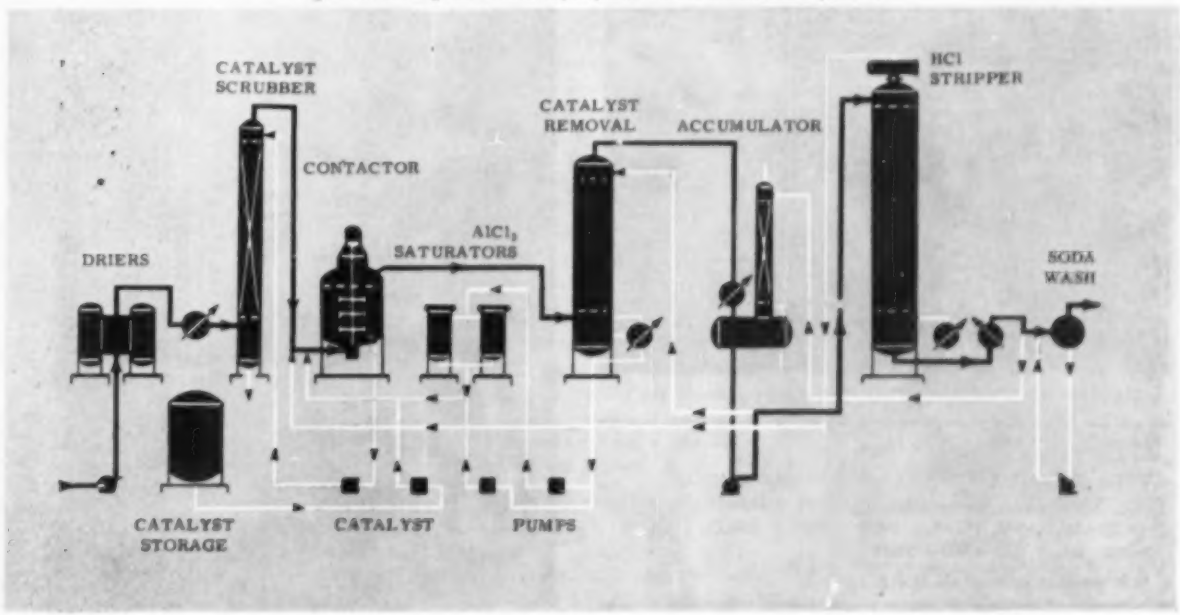
Fig. 3. Reaction sections of the two processes.

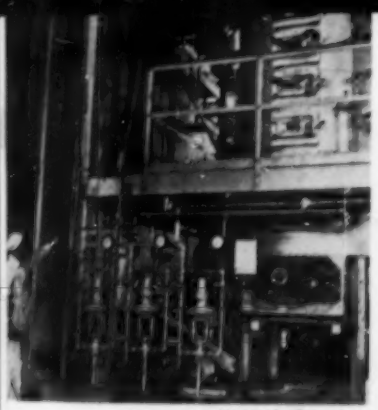


The authors wish to thank their colleagues Messrs. G. E. Liedholm, A. J. Cherniavsky, and W. S. Reveal for useful comments and suggestions which were incorporated in the paper.

* Raw material position, immediate and long-range marketability of the product, development cost, cost of capital, and other business matters.

Fig. 4. Flow diagram of Shell liquid-phase butane isomerization process.





Herreschoff roaster.

ROASTING to remove fluorides from ammonium diuranate

Fluoride contamination in ammonium diuranate formed in a uranium recovery process can be volatilized by calcination above 1,250° F. As a result of tests described below, the authors conclude that this calcination can be carried out more effectively in a fluidized bed reactor than in either a muffle furnace or a raked-tray-type roaster.

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National Lead Company of Ohio
Fernald, Ohio

At the AEC's uranium refinery at Fernald, Ohio,* uranium is recovered from by-products by a series of operations, the first of which extracts and precipitates the uranium as ammonium diuranate. This salt contains fluorides which would be corrosive to the later refining steps, were these fluorides not removed by a calcination operation, which is the subject of this paper.

The process employed in the recovery operation involves a hydrochloric acid leach followed by the precipitation of ammonium diuranate. This ammonium diuranate filter cake is a fine, gelatinous and thixotropic material. It generally contains about 60 per cent moisture, 30-40 per cent uranium (dry basis) and varying quantities of $Fe(OH)_3$, SiO_2, phosphates, and alkaline earth fluorides.

The fluorides present in the cake must be removed prior to subsequent processing as they constitute a corrosion hazard. A high percentage of the fluorides can be volatilized from the cake by high temperature calcination.

* Operated by the National Lead Co. of Ohio.

Chemistry of the Process

The fluorides present in the ammonium diuranate filter cake are volatilized during calcination, probably according to the equations in Table 1.

Equation (1) represents thermal decomposition of ammonium diuranate, reported to start at temperatures in excess of 212° F. (*1*). This is probably the predominant reaction while the filter cake is being heated. The other equations represent mechanisms by which fluoride might be volatilized during calcination. It would be expected that fluoride would react with any undecomposed ammonium diuranate—Equation (*2*). However, it is probable that Equation (3) accounts for the majority of the fluoride volatilized. Fluorides can be quantitatively volatilized at high temperatures (600-1,800° F.) by passing a mixture of air and superheated steam over the sample (*2*). In the case of the more difficultly pyrohydrolyzed materials, such as alkaline earth fluorides, the reaction is more rapid if the sample has been mixed with an excess of U_3O_8, V_2O_5, Al_2O_3, or Cr_2O_3 prior to treatment. As long as the ammonium diuranate filter cake contains a sufficiently large weight ratio of uranium and fluoride, this pyrohydrolytic action provides for the rapid removal of fluoride contamination. The tendency of uranium oxides to react with other filter cake contaminants, especially Fe_2O_3, to form the corresponding uranates or diuranates (*3, 4*) could decrease the quantity of U_3O_8 available for expediting pyrohydrolytic action. Water is furnished to this reaction by

Fig. 1. Ammonium diuranate roasting system.

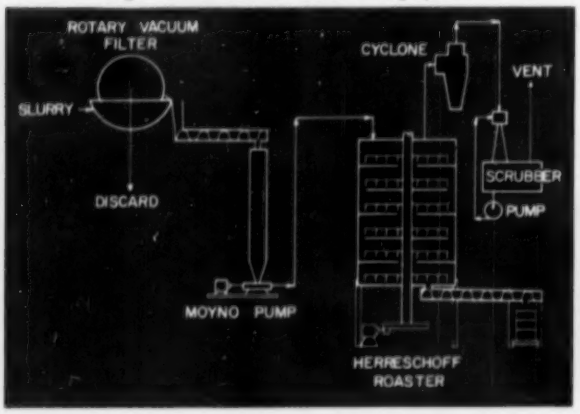


Table 1.

(1) $9(NH_4)_2U_2O_7 \rightarrow 2N_2\uparrow + 14NH_3\uparrow + 15H_2O + 6U_3O_8$

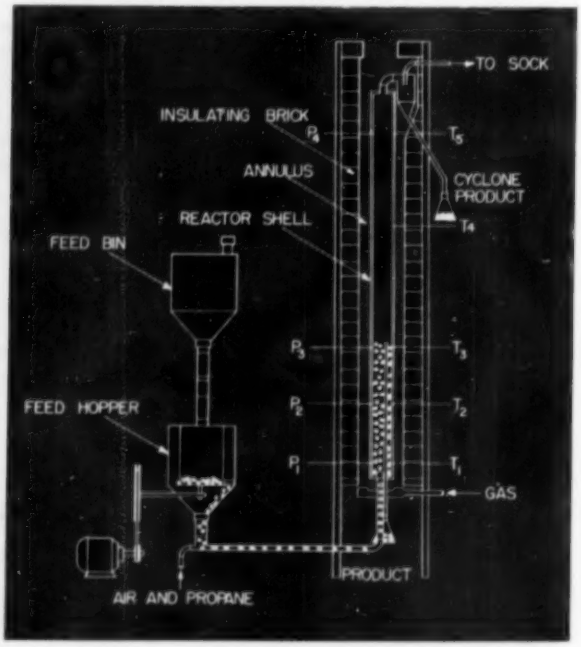
(2) $(NH_4)_2U_2O_7 + MF_2 \rightarrow MU_2O_7 + 2HF\uparrow + 2NH_3\uparrow$

(3) $2U_3O_8 + O_2 + 3MF_2 + 3H_2O \rightarrow 6HF\uparrow + 3MU_2O_7$

(4) $MF_2 + H_2O \rightarrow MO + 2HF\uparrow$

M in equation indicates Ca or Mg.

Fig. 6. Schematic diagram of experimental fluosolids reactor.



moisture in the filter cake and from the water produced during thermal decomposition of the ammonium diuranate. After these sources are depleted, fluoride volatilization diminishes. Additional water may be obtained in practice from (1) air passing through the furnace, (2) combustion of gas in direct fired units, and (3) introduction of steam into the furnace.

Herreschoff Furnace

The uranium recovery plant at Fernald has employed a Herreschoff roaster for calcination of the ammonium diuranate filter cake. The furnace and auxiliary equipment is shown in Figure 1. Ammonium diuranate slurry was filtered on an Oliver rotary vacuum filter (precoated with Dicalite). The cake was scraped off the drum and allowed to fall into a screw conveyor which discharged into a long feed hopper. This hopper fed a Moyno pump which extruded the paste into the top of a six-hearth Herreschoff furnace (rabble arm).

The furnace discharged into a water-jacketed screw conveyor which transported the calcines to a dust-tight drumming station. Off-gases from the furnace were passed through a cyclone dust collector to remove the airborne calcines and then into a caustic scrubber (Schutte-Koerting) which was vented to the atmosphere through an induced draft fan.

The hearths of the furnace were maintained at the following temperatures during operation:

Hearth	Temp. (° F.)
1st (top)	750
2nd	1500
3rd	1650
4th	1750
5th	1750
6th (bottom)	1750

The filter cake had a 1.0-1.5 hr. residence in the furnace.

The bulk of the ammonium diuranate filter cake produced by the uranium recovery facility contained less than 5 per cent fluoride (dry basis). The above furnacing arrangement was successful in reducing the fluoride content to an average of less than 0.5 per cent. However, irregularities in the process preceding the furnacing step occasionally produced larger quantities of fluoride (8-10 per cent). When this occurred, the resulting calcines contained correspondingly higher concentrations of fluoride (1 to 4 per cent).

It was difficult to obtain accurate data on fluoride volatilization without interruption of production. However, trends in plant operation were similar to those in laboratory investigations.

Laboratory Tests

Laboratory calcination experiments were conducted in an electric muffle furnace equipped for introduction of gases. Tests used a static bed of dried ammonium diuranate filter cake.

Results of tests in which filter cake samples with varying fluoride concentrations were subjected to temperatures up to 1,750° F. showed that fluorides did not volatilize appreciably below 1,250° F., but that these temperatures produced a marked increase in fluoride volatilization rate (Figure 2).

Rates of fluoride volatilization from the same samples, during calcination at 1,750° F., are shown in Figure 3.

The effect of a gas sparge during calcination is shown in Figure 4. In three separate trials, nitrogen, air, and steam were introduced into the furnace at low velocities (1.3-1.4 displacements/min.). Use of nitrogen did not affect the fluoride volatilization rate, but air was beneficial during the first 3 to 4 hours of treatment. Use of steam caused a marked increase in fluoride volatilization rate, especially during the first hour of calcination. This probably resulted from pyrohydrolytic action of steam on alkaline earth fluorides.

Effect of bed depth (diffusional effects) is shown in Figure 5. Increases in the bed depth during calcination caused a corresponding reduction in fluoride volatilization efficiency.

Fluid Bed Calcination

Consideration was given to the use of a fluidized bed furnace for calcination of ammonium diuranate cake. A number of fluidized bed tests were made at the Dorr Company's Westport Mill Laboratory in a 4-in. Fluosolids furnace. Test results indicated that the fluid bed furnacing technique was more satisfactory than the Herreschoff furnace in producing low fluoride calcines from ammonium diuranate filter cake contaminated with up to 15 per cent fluoride (*5*).

FEED PREPARATION

To obtain satisfactory particle size and shape for good fluidization, three methods of feed preparation were investigated:

(1) pelletizing by mixing wet and dry cake

(2) drying the cake in a Herreschoff furnace followed by controlled crushing and screening

(3) extrusion of the wet cake through a perforated plate followed by drying in an oven and crushing in a granulator (Stokes)

Fluoride volatilization studies were conducted on the products of the first two operations only.

Spherical pellets could be produced by blending wet and dry powdered cake to an optimum moisture content. These pellets, after case hardening by a short drying period, had good fluidizing characteristics. This technique, however, required a large recycle of furnace product. An alternate method of obtaining

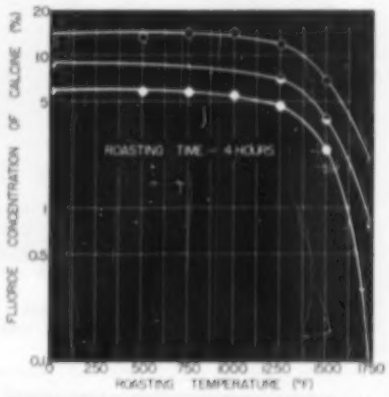


Fig. 2. Effect of temperature on fluoride volatilization during roasting of ammonium diuranate filter cake.

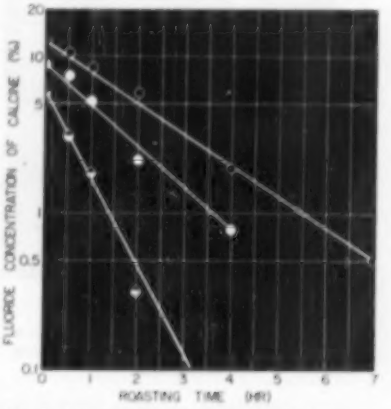


Fig. 3. Rates of fluoride volatilization from ammonium diuranate filter cake samples during calcination at 1,750° F.

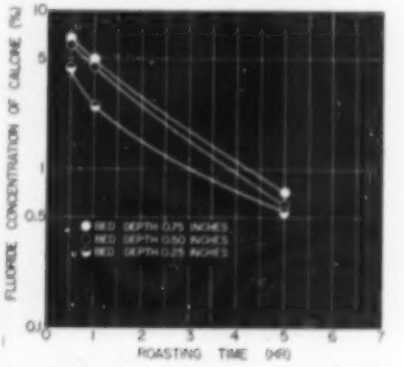


Fig. 4. Effect of gas sparging on rate of fluoride volatilization from ammonium diuranate during roasting (1,750° F.).

the same moisture content by partial drying of the wet cake was less successful in producing pellets of satisfactory structural characteristics.

A satisfactory furnace feed was also produced by completely drying the filter cake in a Herreschoff roaster, followed by a granulation of the resulting agglomerates. Fines were screened out and reintroduced to the screw conveyor at the base of the filters. In this way the dried fines were blended with the wet filter cake as it came off the filter.

A third feed preparation technique involved extrusion of the ammonium diuranate through a perforated plate onto trays. The trays were then placed in an oven and the dried material was granulated.

The latter two drying techniques appeared most satisfactory for feed preparation, since less control was necessary and product recycle was not required.

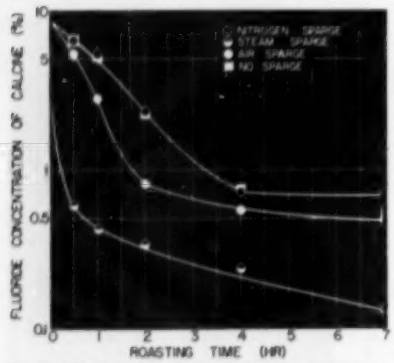


Fig. 5. Effect of bed depth on fluoride volatilization during roasting ammonium diuranate cake (1,750° F.).

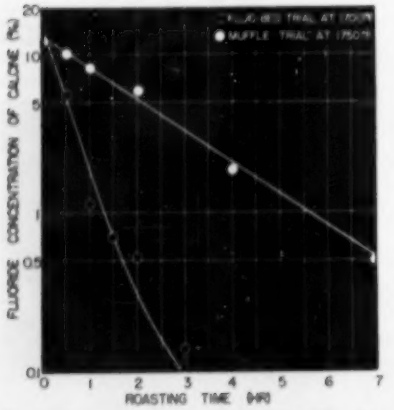


Fig. 7. Comparison of fluoride volatilization efficiencies of muffle and fluid bed furnacing techniques.

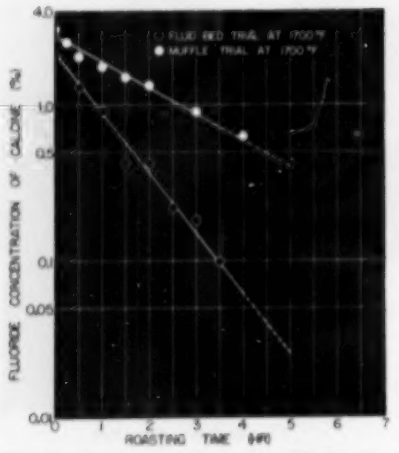


Fig. 8. Comparison of fluoride volatilization efficiencies of muffle and fluid bed furnacing techniques (dried diuranate cake).

FLUID BED TESTS

The 4-in. experimental reactor is diagrammatically illustrated in Figure 6. It consisted of a 4-in. I.D. stainless steel tube (Type 310 SS) 9 ft. long encased in a firebrick housing. The firebrick was so placed as to form an annulus between the brick and the reactor tube, thus permitting a series of burner tips in the base of the annulus to direct a flame along the outside wall of the reactor. This practice is not employed in commercial units but is necessary in laboratory equipment where the ratio of wall area to bed volume is large and heat losses are correspondingly high. Maintaining temperature in the experimental reactor solely by internal gas combustion exaggerates the concentration of combustion products in the gas phase.

Air and propane were metered through flowrators; the two gases were mixed and then passed into the reactor. Pellets were placed in the feed bin which fed a hopper equipped with a rotary disc situated about ¼-in. below the pellet supply. Pellets, seeking their angle of repose, flowed through the opening onto the disc. On the disc they were rotated to a stationary scraper blade which dropped them into the gas stream. The pellets, airborne in the fluidizing gas stream, were fed into the bottom of the reactor. In the bed the feed was brought into a high degree of turbulence and assumed the reaction temperature almost immediately. After a set retention time the pellets dropped into an overflow pipe and were collected as product. Solids entrained in the gases leaving the furnace were disengaged in a small cyclone collector which was vented to atmosphere through a sock dust collector.

The reactor had four pressure and five temperature taps situated along its side.

EXPERIMENTAL RESULTS

Samples of both the pelletized filter cake and the dried, granulated material were subjected to fluidized bed calcination. Figures 7 and 8 show comparisons of the fluoride volatilization efficiencies of the fluidized bed and laboratory muffle furnaces. The comparison shown in Figure 7 is qualitative only, since the samples were from different lots of material. Feed to the fluid bed furnace was pelletized, while that used in the laboratory was a dry powder. However, the results shown in Figure 8 were achieved with identical feed materials. It can be seen that the fluidized bed furnace provided a considerably more effective means of fluoride volatilization than did the laboratory muffle furnace (or the Herreschoff roaster). This was probably the result of more efficient removal of gaseous reaction products, more uniform temperature control and more intimate contact between solids and combustion products in the fluidized bed furnace. These effects were most noticeable where a very high fluoride contamination was present in the filter cake.

Conclusions

Fluoride contamination in ammonium diuranate can be volatilized by calcination at temperatures in excess of 1,250° F. Completeness of fluoride removal depends on:

(1) residence time in the furnace at calcination temperature

(2) quantity of water vapor (or steam) present during calcination

(3) intimacy of contact between steam and filter cake.

Steam can be provided in suitable quantities to any furnacing arrangement. However, intimate contact between solids and gases is obtained more efficiently in a fluidized bed furnace than in either a laboratory muffle furnace or a Herreschoff roaster. Calcination in a fluidized bed furnace was substantially more effective in volatilizing fluoride contamination from ammonium diuranate filter cake than was a laboratory muffle furnace (or Herreschoff roaster), especially at higher levels of fluoride contamination.

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Presented at A.I.Ch.E. meeting, Pittsburgh, Pennsylvania.

As chemical engineering extends the use of high-pressure processing techniques, the question of strength of materials becomes increasingly vital to equipment designers. Phenomena connected with hydrogen embrittlement of steels are assuming particular importance, even at normal temperatures. This article is the second * which C.E.P. has published in recent months on important developments in this little-understood field.

HYDROGEN EMBRITTLEMENT of cold-worked metals

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The embrittling effect of nascent or atomic hydrogen on various materials employed as cathodes during electrolysis has long been known. According to a recently proposed mechanism (*5*), hydrogen, like a metal, forms alloys at the metal surface during chemical or electrochemical reaction and "plates into" the surface. An older, more widely accepted view (*8*) holds that a portion of the atomic hydrogen which forms as discharged ions in intimate contact with the metal surface, is able to penetrate the surface along slip planes or planes of discontinuity in the crystal lattice. In either case, diffusion of monatomic hydrogen into the metal will take place until larger faults, open grain boundaries, inclusions, etc., are reached, at which points recombination to molecular hydrogen can occur. The hydrogen so formed is trapped at ambient temperatures, and the steady-state concentration of atomic hydrogen on the surface will propagate the process until extremely large pressures of molecular hydrogen build up inside the material. The accumulated hydrogen pressure can open up larger cracks and materially weaken the metal. X-ray studies (*2*) of various magnetic alloys impregnated with cathodic hydrogen have revealed line broadening which could be associated with an internal stress due to hydrogen of thousands of atmospheres. Brittle failures result possibly because the hydrogen forms high stress inclusions at the grain boundaries, and permanent deformation by slippage along these boundaries is highly restricted.

Gaseous hydrogen at elevated temperatures also can embrittle steels and nonferrous alloys. The process can be likened to that discussed except that the necessary atomic hydrogen is formed by thermal dissociation. From a consideration of the free energy of dissociation for the reaction $H_2 \rightarrow 2H$ it can be shown that significant pressures of atomic hydrogen are present only above ~200° C. At a given temperature the pressure of atomic hydrogen, according to the equation of mass action, increases as the square root of the hydrogen pressure. Studies of the solubility in and diffusion through metals of high-temperature hydrogen show that rates are proportional to the square root of pressure; this lends support to the theory that only atomic hydrogen permeates metals. At high pressure and high temperature, hydrogen is extremely mobile and reactive. In this state hydrogen can attack carbon in metals and inflict additional destruction due to decarburization and internal stresses caused by the high-pressure methane formed (*6*).

The deleterious effect of high-pressure hydrogen at *room temperature* on the mechanical properties of various steels

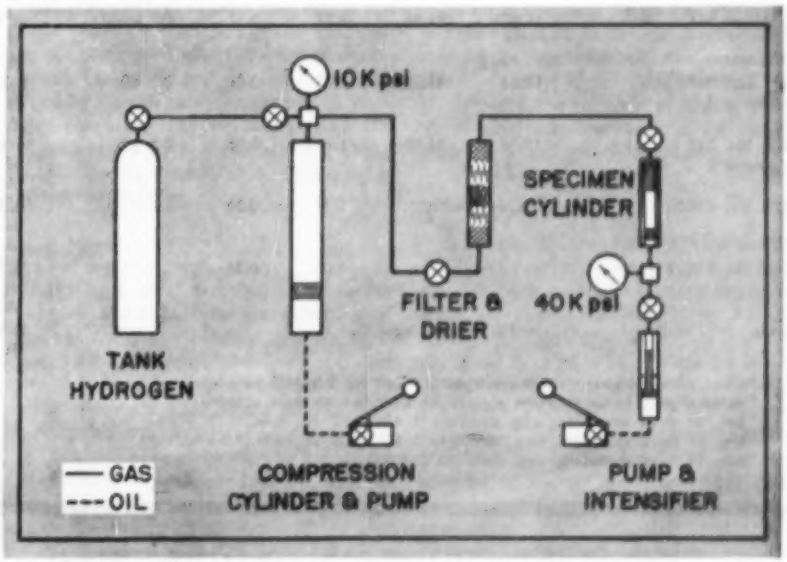

Fig. 1. Pressure system.

Work done under the auspices of the U. S. Atomic Energy Commission.

* See Van Ness and Dodge (C.E.P., 51, 266, 1955).

and nonferrous alloys has recently been reported by several investigators (*1, 9*). It has been noted that sorption of the high-pressure gas in some way causes a brittleness in certain metals which may be accompanied by loss of ultimate strength. Although embrittlement may follow a process similar to that just described, it is difficult to account for the atomic hydrogen required. At 25° C. the dissociation constant for hydrogen is calculated to be $\sim 10^{-73}$ atm. Even at hydrogen pressure of 100,000 atm. the partial pressure of atomic hydrogen has the infinitesimal value of $\sim 10^{-38}$ atm., which implies only one dissociated pair of hydrogen atoms in 10^{11} l. of high-pressure gas. If room-temperature embrittling is to be explained by existing concepts, one requires therefore some sort of process, involving perhaps adsorption, catalysis, or corrosion which can produce a steady-state concentration of hydrogen atoms on the metal surface. On the other hand, it may be postulated that at high pressures molecular hydrogen can be driven into the metal through enlarged cracks and fissures, although it is hard to explain why helium, for example, does not behave similarly.

To date no really fundamental studies have been made of the mechanism by which these room-temperature effects are brought about. Rather, the approach has been first to define the problem and second to make qualitative or semi-quantitative measurements from the practical standpoint of finding hydrogen resistant alloys. This study embraces both aspects of this approach.

The authors were introduced to the problem when several bourdon gauges failed after room-temperature exposure to hydrogen for times as short as one minute and at pressures as low as ⅔ full scale, even though these gauges had been previously calibrated with oil, cleaned, and successfully leak tested for several days with helium at full-scale pressure. Admittedly a bourdon tube is not a conservatively designed pressure vessel. Further, an embrittled tube should be liable to rupture when flexed. (This point is supported by the fact that all the gauge failures occurred during or immediately following pressure changes in the hydrogen system.) However, subsequent failures of steel and Monel capillaries at room temperature and hydrogen pressures of 30,000 lb./sq. in., where wall thicknesses were adequate to confine other gases at pressures up to 60,000 lb./sq. in., and no flexure was involved, have made it clear that a practical problem really exists. Circumstances attending several capillary failures suggested that perhaps prior cold-working of the material made it susceptible to hydrogen embrittlement. It was to clarify this point in particular, and to find hydrogen resistant alloys in general, that this empirical study was undertaken.

Experimental

GENERAL METHOD

Test samples in the form of strips were inserted in the upper end of a high-pressure cylinder. The cylinder was charged with hydrogen to 40,000 lb./sq.in. by a two-stage process utilizing oil pressure. Following isolation at room temperature (nominally 25° C.) for 20 hr., the system was depressured and the samples were immediately placed in a bend machine and bent through successive 180-deg. bends until broken. Corresponding control samples were also broken and the ratio of the number of bends necessary to break exposed samples to the number necessary to break controls was taken as a measure of the change in ductility.

A parallel study of the embrittling effect of cathodic hydrogen on identical specimens was carried out for comparison with results of these pressure studies. Test samples were exposed as cathodes for 30 min. in a dilute sulfuric acid bath at a current density of 1 amp./sq.in., after which they were broken in the bend machine.

MATERIALS

Seven materials were examined for the possible effect of prior cold-working on susceptibility to room-temperature hydrogen embrittlement. These included four stainless steels, two carbon steels and beryllium copper.

Table 1.—Chemical Composition and Mechanical Properties of Materials Studied

Material	Chemical Composition					Mechanical Properties			
						Hardness	Tensile strength,[a]	0.2% Yield strength,[d]	Elongation 2 in.,[e]
	% Cr	% Ni	% Mn	% C	% other		10^3 lb./sq.in.	10^3 lb./sq.in.	%
AISI No. 303	18.31	12.30[a]	1.03	0.08	0.03 S[b]	A	90.5	58.3	51
						¼ H	98.4	79.7	39
						H	171.5	153.3	7
AISI No. 316	16.87	11.54	1.77	0.07	0.7 Mo[b]	A	100.2	49.8	61
						¼ H	111.3	79.7	42
						H	189.9	158.9	5
AISI No. 347 Source A	17.86	11.39	2.06	0.05	0.7 Cb	A	93.5	44.0	48
						¼ H	103.8	79.4	34
						H	173.3	144.4	6
AISI No. 347 Source B	17.06	11.19	1.40	0.06	0.9 Cb	A	92.3	44.3	47
						¼ H	102.7	76.7	32
						H	171.2	146.4	6
AISI No. C1020	.....	.....	0.1[b]	0.20	...	A	59.2	32.4	23
						¼ H	72.3	67.5	5
						H	104.4	103.6	2
AISI No. C1022	.....	.....	1.0	0.21	...	A	66.7	42.1	28
						¼ H	83.7	80.1	8
						H	114.9	114.6	3
BeCu	~2% Be, remainder Cu					A	59.8	26.2	56
						¼ H	66.6	50.8	39
						H	120.4	111.3	5

[a] value slightly higher than the composition limit for this AISI notation.
[b] value slightly lower than the composition limit for this AISI notation.
[c] avg. of three specimens; avg. deviation ± 1.0 × 10^3 lb./sq.in.
[d] avg. of three specimens; avg. deviation ± 1.2 × 10^3 lb./sq.in.
[e] avg. of three specimens; avg. deviation ± 0.5%.

Spectrometric and wet-chemical analyses were performed on all materials; the results are given in Table 1. Although several values fall outside established composition limits, the following probable AISI numbers have been assigned to the steel specimens: 303, 316, 347 (A and B from two different sources), C1020, and C1022. Identity of the beryllium copper was confirmed by the analysis.

Annealed sheets, 1/16 in. thick, were prepared from each material. In addition each material was cold-rolled from the annealed state to two conditions of hardness with a final thickness of 1/16 in. In one case the starting thickness was such that the cold-rolling gave a reduction in area of 37.1%, corresponding to full hard; in the second case the reduction was 10.9%, corresponding to *1/4 hard*. Three standard ASTM rectangular tension test specimens were prepared from each material sheet in each of the three hardness states. Results of tensile tests performed on these specimens are presented also in Table 1.

Twelve specimens 2.165 × .394 × 1/16 in. (55 × 10 × 1.55 mm.) were then prepared from each sheet—three to be exposed to high-pressure hydrogen, three to be exposed to cathodic hydrogen, and six to serve as controls. Prior to hydrogen exposure the specimens were thoroughly degreased with acetone. Within 8 to 15 min. following exposures the samples were broken in the bend machine. A preliminary study indicated that for hydrogen-embrittled specimens no measurable recovery in ductility is made within this time.

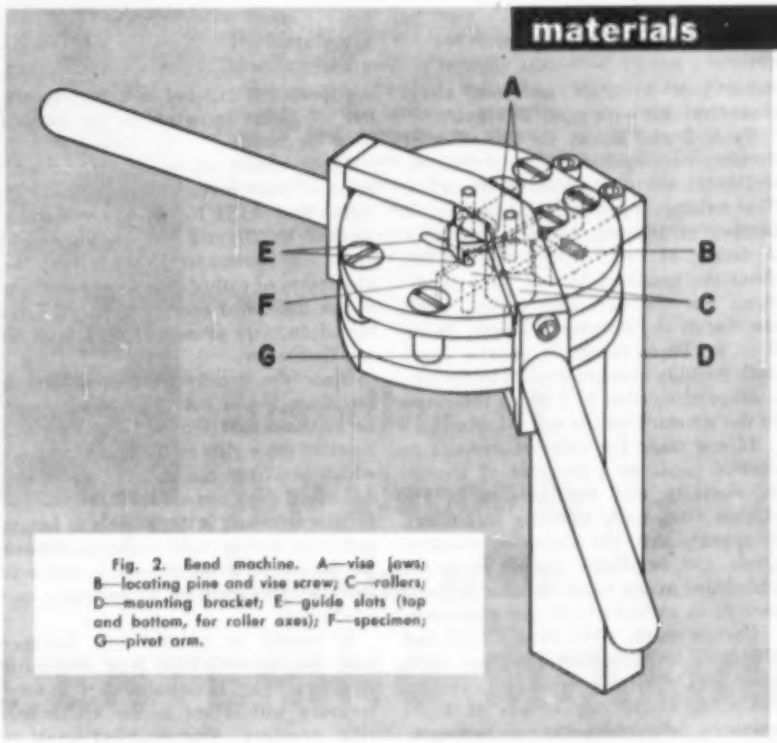

Fig. 2. Bend machine. A—vise jaws; B—locating pins and vise screw; C—rollers; D—mounting bracket; E—guide slots (top and bottom, for roller axes); F—specimen; G—pivot arm.

PRESSURE SYSTEM

It had been shown (*9*) that many materials may be dangerously embrittled at room temperature by 30,000 lb./sq. in. hydrogen but that austenitic stainless steels prove resistant to such embrittlement. For this reason the specimen cylinder was machined from AISI No. 347 stainless steel. The lower bore of the cylinder was of ¼ in. diam. by 9 in. long; it was smoothed to take a floating brass piston fitted with O-rings. The upper bore was slightly larger in diameter and accepted six strip specimens in a holder with little dead volume. The cylinder cap, which was attached to a filling tube and valve, was closed with a lens ring.

The pressuring system is shown in Figure 1. Ordinary tank hydrogen was brought to 10,000 lb./sq. in. by a commercial compression cylinder, filtered and dried at high pressure and then admitted to the specimen cylinder. The movable piston, originally at the bottom of the specimen cylinder, was then pumped up with oil from an intensifier until a pressure of 40,000 lb./sq. in. obtained in the oil system. A gauge in the oil line was used to monitor pressure for the prescribed exposure time. By placing the gauge at this point one can reduce the dead volume in the gas system and also protect the bourdon tube from the embrittling effects of hydrogen. The pressure differential across the floating piston which sealed oil from gas was negligibly small.

ELECTROLYTIC SYSTEM

The electrolytic bath consisted of a 4% H_2SO_4 aqueous solution "poisoned" with CS_2 and P. Three test specimens at a time were suspended as cathodes in the bath equidistant from a platinum gauze anode. Direct current was supplied by a small battery charger. A variable resistance was adjusted periodically to maintain a current density of 1 amp./sq. in. during the 30-min. exposure at room temperature.

BEND TEST

A simple bend test has been shown to give a rather sensitive measure of the embrittlement suffered by metals exposed to hydrogen. The hand-operated bend machine is shown in Figure 2. A strip specimen was locked in place by a locating pin and was supported up to the point of bend by smooth vise jaws. Specimens were bent first 90 deg. in one direction over a ¼-in. roller by a second roller, then similarly 180 deg. in alternate directions. The first bend and the last bend during which the specimen broke were each given a count of ½; all 180-deg. bends were counted one. Bends were executed at the rate of 144 deg./sec. in the following sequence; +90-deg. bend in ⅝ sec., relax 1¼ sec., −180-deg. bend in 1¼ sec., relax 1¼ sec., +180-deg. bend in 1¼ sec., etc. In this manner the specimen every 1¼ sec. was alternately bending at ±144 deg./sec. and 0 deg./sec. The bend test in general was reproducible to about ±5%.

Besides the total bends to break, the per cent elongation of 1-in. gauge marks scribed on the samples was measured. This quantity could be correlated directly with the number of bends for a given material; therefore, it apparently gave no additional information.

Discussion of Results

Averages of the number of 180-deg. bends necessary to break multiple samples of each material in each hardness state are summarized in Table 2. The entries in Cols. 3, 4, and 5 of Table 2 are good to ±5%. The irreproducibility is due in part to slight variations in thickness of specimens, the thinner specimens not being forced through a full 180 deg. by the bend machine. An attempt to correct for this effect made it clear that other variables such as

minor pits, scratches, and local stress concentrations were more significant.

Table 2 also shows the variation of ductility with cold-working for the control specimens of the different materials. The stainless steels suffer a decrease in number of 180-deg. bends to break by a factor of ~2.5 when cold-worked from the annealed to full hard condition. For the two mild carbon steels the factor is somewhat larger, being 3 or 4. These results in general agree with ductility changes implied by the percentage elongation in 2 in. as measured in the standard tensile test (Table 1).

If one takes the ratio of *exposed* to *control* bends as a measure of change in ductility and considers a ±10% change from unity as being significant, it appears that the austenitic stainless steels and beryllium copper were not embrittled in any hardness state by pressure or by cathodic hydrogen exposures.

Carbon steels AISI Nos. C1022 and C1020 in the annealed condition show good and moderate resistance, respectively, to embrittling effects of high-pressure, room-temperature hydrogen. With prior cold-working of these mild steels to ¼ hard however, the ductility ratio of exposed to control samples in Table 2 drops by a factor of 2.5 and 3. With prior cold-working to full hard it drops by a factor of 4 over that for annealed samples. The apparent difference in ductility ratio for the two steels lies just outside the experimental error but is probably not significant. Specimens of carbon steel subjected to the action of cathodic hydrogen exhibit embrittlement which is similar to that for specimens exposed to high pressure, but somewhat more severe for the *full hard* specimens.

These results are in agreement with those of other investigators (*3, 7*), who found that AISI No. C1020 steel cold-worked to 25 and 45% reduction in area was permanently embrittled by absorption of cathodic hydrogen whereas in the hot-rolled condition the steel retained ductility as measured by a standard tensile test.

Since the density of cold-worked is less than that of hot-rolled steel, it may be assumed that the cold-worked metal contains more rifts in the lattice through which hydrogen can diffuse. From this and other work one would infer that the ferritic structure is more likely to fissure and rift during cold-working than is the austenitic structure which seems to be inherently resistant to hydrogen embrittlement.

It should be pointed out however that, on cold-working, the austenitic structure which is unstable at room temperature will revert to the stable ferritic structure. Our stainless steels in the annealed condition were nonmagnetic; in the ¼ hard state they showed a trace of ferromagnetism and in the full hard state were moderately ferromagnetic, which indicates an increasing amount of ferrite with cold-working. After a specimen had been broken in the bend machine its fractured ends were strongly ferromagnetic regardless of previous hardness state (*4*).

It is concluded that the presence of cold-formed ferrite in austenite does not significantly lower the resistance of the stainless steel to hydrogen embrittlement under the test conditions of high pressure or electrolysis.

The parallelism between the results obtained by high-pressure room-temperature exposure and by cathodic exposure to hydrogen would suggest that the mechanism for hydrogen impregnation of metals is the same in both cases. However, studies of a more fundamental nature are needed to establish this as fact.

Acknowledgment

Contributions to this research by M. C. Smith, C. F. Metz, and C. G. Hoffman of the Los Alamos Laboratory, who supervised the cold-rolling, the chemical analyses, and the tensile tests, respectively, are acknowledged.

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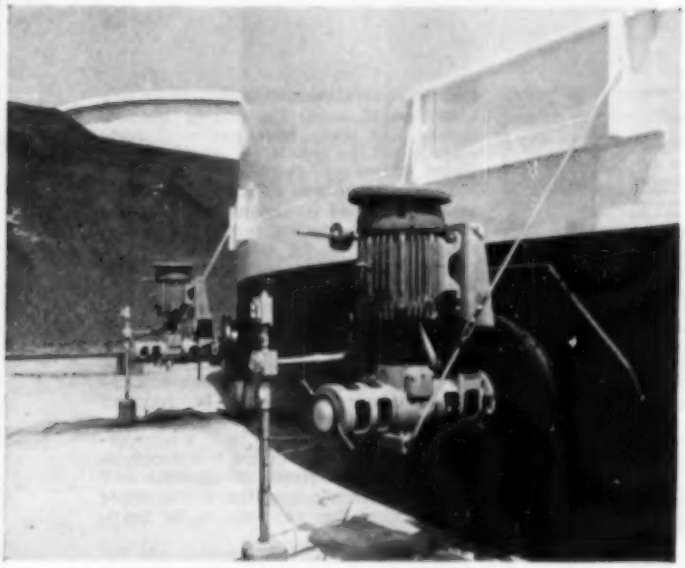
Table 2.—Results of Bend Test

Material	Hardness	Number of 180-deg. bends to break			Ratio, expos./control	
			H_2 expos.[b]			
		Control[a]	Pressure	Cathode	Pressure	Cathode
AISI No. 303	A	25.3 ± 2.1	24.0 ± 2.0	27.0 ± 1.3	.95 ± .16	1.07 ± .14
	¼ H	22.2 ± 1.2	21.3 ± 1.6	20.7 ± .9	.96 ± .12	.93 ± .09
	H	12.0 ± .7	9.7 ± .4	13.0 ± .7	.81 ± .08	1.08 ± .12
AISI No. 316	A	28.2 ± 1.2	27.3 ± 1.6	27.3 ± .4	.97 ± .10	.97 ± .06
	¼ H	24.8 ± 1.2	26.7 ± 1.1	26.0 ± .7	1.08 ± .10	1.05 ± .08
	H	10.5 ± .8	9.7 ± .4	11.7 ± .4	.92 ± .11	1.11 ± .12
AISI No. 347 Source A	A	21.8 ± 1.5	21.3 ± 1.1	22.0 ± .7	.98 ± .12	1.01 ± .10
	¼ H	18.3 ± .8	17.8 ± 1.2	19.0 ± .7	.97 ± .11	1.04 ± .08
	H	8.5 ± .7	8.7 ± .4	8.7 ± .4	1.02 ± .13	1.02 ± .13
AISI No. 347 Source B	A	22.3 ± 1.4	21.3 ± .4	22.7 ± .9	.96 ± .08	1.02 ± .11
	¼ H	19.2 ± .8	17.3 ± .4	19.7 ± .9	.90 ± .06	1.03 ± .09
	H	8.8 ± .6	8.0 ± 0	9.7 ± .4	.91 ± .06	1.10 ± .12
AISI No. C1020	A	19.5 ± 1.2	14.3 ± .4	13.3 ± .4	.73 ± .07	.68 ± .06
	¼ H	13.5 ± 1.8	3.0 ± .7	3.0 ± .7	.22 ± .08	.22 ± .08
	H	4.8 ± .3	0.9 ± .7	0.3 ± 0	.19 ± .16	.06 ± 0
AISI No. C1022	A	22.3 ± 2.0	20.7 ± .4	16.3 ± .4	.93 ± .10	.73 ± .08
	¼ H	18.0 ± .7	7.7 ± .4	3.7 ± .4	.43 ± .04	.21 ± .03
	H	7.4 ± .5	2.0 ± 0	0.3 ± 0	.27 ± .02	.04 ± 0
BeCu	A	38.5 ± 3.5	35.0 ± 1.3	32.7 ± 1.1	.91 ± .12	.85 ± .11
	¼ H	32.0 ± 2.3	33.3 ± 1.1	30.3 ± 2.9	1.04 ± .11	.95 ± .16
	H	14.7 ± 1.4	15.7 ± .4	15.3 ± 1.1	1.07 ± .13	1.04 ± .17

[a] avg. of six specimens; [b] avg. of three specimens.



Side-entering propeller-type mixer on 80,000-bbl. gasoline blending tank. Two 25 hp. mixers placed on 120-ft. diam. × 40-ft. high tank.

The blending of liquids in large storage tanks where density stratifications exist is a daily operation in the petroleum refining and chemical industries. Nevertheless, the mechanics of the blending operation have not been sufficiently well understood. Here is a report of a study which took place in tanks as large as 70,000 gallons, and which showed that large impellers (with respect to tank sizes) give better results than small ones for the same power; that longer blending time at lower power levels does not consume more power.

blending of low-viscosity liquids with SIDE-ENTERING MIXERS

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Blending is a common operation in fluid mixing.* The manner in which blending takes place is varied, but the extremes are:

a. introducing a second miscible fluid into a first fluid in the vessel in such a manner that uniformity is produced almost instantaneously as the second fluid is introduced;

b. adding the second fluid in such a manner that the two liquids are initially stratified before blending progresses.

This report presents information concerning the second mode of blending, in which the two liquids are initially stratified before blending begins. This is by far the most difficult case, one which should yield useful limiting values for the effect of certain variables on the mixing operation.

The entire study was made with side-entering propeller-type mixers, positioned in the majority of the runs in the "standard off center" position. This position is illustrated in Figure 1. Tank sizes of 70,000, 500, and 100 gallons were used in the experiments. Fluid viscosity was between 0.3 and 1.0 centipoises.

Various systems have been used in the laboratory for measuring the effect of blending. Included are pH, color, electrical conductivity, concentration, refractive index, and density. In this particular study, uniformity of temperature was used as a measure of blending thoroughness. The use of hot and cold layers of the same fluid gave results similar to those obtained in blending of different fluids having the same physical properties as the hot and cold fluids. Blending times ranged from one minute to six hours. The effects of several mixing variables were studied and are reported and discussed as follows:

Results: Discussion and Conclusions

There was found to be a very sharp and distinct barrier between the two stratified layers. The mechanism by which this barrier is worn away seems to be a gradual erosion or wearing away of the barrier by the fluid in the part of the tank moved by the mixer.

Once the impeller action begins, the fluid motion begins quickly in the lower uniform area. No motion appears at the top surface of the upper stratified layer until the boundary layer reaches this surface.

Some preliminary experiments with injecting the second fluid behind the propeller indicate blending times several factors lower than that required for initially stratified systems.

The wearing away of the interface seems to be largely proportional to the volume of fluid passing across the interface. Thus, large impeller size to tank size ratios which give larger flow capacities for the same amount of power give shorter blending times for the same level of power than do smaller D/T ratios. There is apparently enough turbulence in low-viscosity systems that once any fluid from the second layer is incorporated into the first layer, it is immediately blended uniformly throughout.

The use of small diameter impellers, or more generally, small diameter fluid jets, would indicate more power for the same blending performance. This has been confirmed by the theoretical discussions of Folsom (*1*) and the experimental data of Fosset and Prosser (*2*). These authors give the conditions required to mix fluid in initially uniform layers and to prevent stratification throughout the entire system. Their results are in agreement with the results of this paper in that large diameter

* And yet few fundamental studies have been made in this area. Publications by Fox and Gex (*3*), and Vandervusse (*5*) are the major ones to date in this field. Articles on the use of fluid jets for mixing in which the fluid jet may be produced either by flow from a nozzle or from a mixing propeller have appeared in the literature (*1*, *2*).

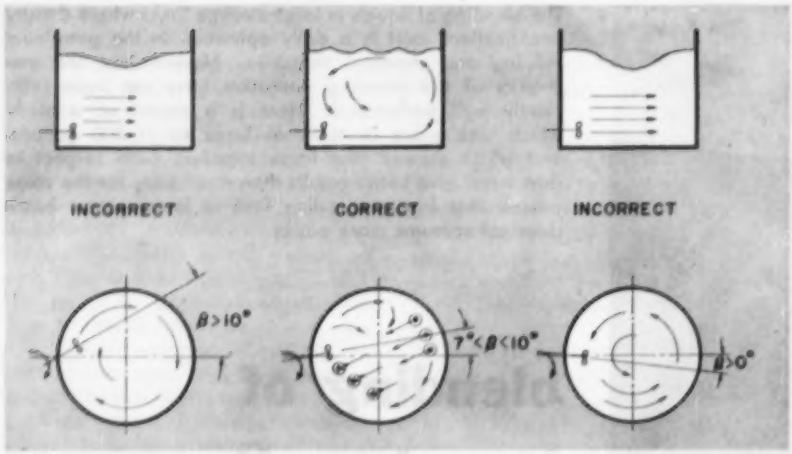

Fig. 1. Optimum positioning for side-entering propeller-type mixers.

fluid jets give better performance at lower horsepower than do small diameter fluid jets, whether the jet is produced by mixers or nozzles.

One important difference exists between the data presented here and the data of Fossett and Prosser on the use of nozzles. They have found (2) that the nozzle could not mix a tank initially stratified. Therefore, all their data are for injection of a second fluid into an initially uniform fluid, which requires much less power input than does the case of initially stratified layers presented here.

At no time in this investigation did data indicate that blending could not be obtained even at long time intervals with low power levels. There was some concern whether very low power levels would have all their energy dissipated in internal friction of the fluid without having a chance to cause blending throughout the system. Within the range of practical interest (blending times up to 12 and 16 hours) indications were that blending would proceed, and that these long blending times were entirely feasible.

Results: Summary

EFFECT OF DENSITY DIFFERENCE BETWEEN STRATIFIED LAYERS

The difference between hot and cold layers is essentially a difference in gravity. By varying the temperature difference and making duplicate blending runs, it was established that the blending time was proportional to the difference in gravity to the 0.9 exponent.

$$\theta a(\Delta\rho/\rho_o)^{0.9}$$

The range of density differences used in the experimentation was from 0.3% to 7%.

EFFECT OF POWER

Power was varied by varying the speed of a given size impeller. The effect of power on blending time indicates that power and blending time are inversely proportional:

$$\theta a(HP)^{-1}$$

where HP is the power input to the fluid. θ varied from one minute to six hours.

IMPELLER SIZE TO TANK SIZE RATIO

In the blending of low-viscosity fluids, the major effect seems to be one of pumping action throughout the tank. The use of large impellers at slow speed gives large values of flow and low values of fluid shear. In blending operations the impeller diameter to tank diameter ratio (D/T ratio) are normally relatively low and in all respects these studies were made to simulate blending on large scale installations.

The effect of D/T was correlated at constant power input to the mixer; therefore, large D/T inputs are associated with slow speeds to give the same power input as small impellers. With D/T values ranging from 0.03 to 0.11, the best exponent was found to be -2.3 at a liquid level to tank diameter ratio (Z/T) equal to 1.

$$\theta a(D/T)_{HP}^{-2.3}$$

There is evidence that as the tank batches become shallower, the effect of D/T becomes less.

EFFECT OF MIXER POSITION

A mixer angle of 7° to 10° was used, as angles appreciably different from these values give inferior blending results.

Details of Experiments

EQUIPMENT

The mixing equipment used in this investigation consisted entirely of side-entering mixers, electrically driven through a mechanical means for varying impeller speeds. The shafts were positioned horizontally and the impellers used were three-bladed marine-type propellers.

The fluid used was water. The temperature of the fluid in various positions was measured by mounting copper-constantan thermocouples in the tank. The thermocouple temperatures were recorded on Brown thermocouple recorders.

Two types of thermocouple recorders were used in this work. One was a 16-point multi-channel recorder. With this instrument, up to 16 thermocouples could be placed in the tank and each thermocouple temperature would be recorded every four minutes. If less than 16 thermocouples were used in the tank, a temperature record of some of the thermocouples could be had at intervals of less than four minutes by connecting the thermocouple leads to more than one point on the multipoint recorder.

The second type of thermocouple recorder was a single channel strip chart recorder. The thermocouple outputs were fed to this recorder through a 16-point multiple contact switching box. The switching box was operated manually, so that the operator could record the temperature of any thermocouple point at any time and for as long a period of time as desired. With this recorder it was necessary to mark the chart paper with an identification of the thermocouple being recorded. Since the chart speeds were constant and known values for these recorders, the blending time could be determined by measuring the length of the chart that passed through the recorder from the beginning until the end of the run.

The tanks used in this investigation were flat bottomed, unbaffled, vertical cylindrical tanks. The tank diameters were 240 inches, 54 inches and 30 inches.

EXPERIMENTAL METHOD

To determine whether a blending operation has proceeded to homogeneity, it is necessary to be able to measure some fluid variable at various points in the tank. For this study the measurement of variation in temperature within the tank contents was investigated because of the following factors:

1. **Simplicity of measurement.**
2. **After a blend, fluids could be re-used because their properties could be adjusted by temperature adjustment.**

To determine if such a method were feasible, a 42-inch tank was set up and filled to a 21-inch depth with cold water. A layer of hot water was then floated on top of the cold by directing the stream of hot water onto a float, so that the water velocity was directed horizontally. It was found that a good separation of the hot and cold layers could be obtained. Figure 2 is a graph of the temperature changes in this tank when it was allowed to stand without mechanical agitation for a period of 48 hours. It can be seen that the temperatures of the hot and cold layers approached room temperature without any interchange between the two layers.

To determine the feasibility of the temperature method of measuring blending time, a flat-blade turbine mixer was placed in a tank of water in which hot and cold layers had been placed. It was found that the blending proceeded from the high density layer upward in the tank. As mixing proceeded, the interface moved upward and when it reached the position of the thermocouple, the temperature at that position dropped until it became equal to the temperature of the liquid in motion below the interface.

As a further check on this mechanism of blending, visual tests were made in which one of the layers was colored with a dye. In these demonstrations, it was easily seen that fluid flow due to the impeller was restricted to the lower or more dense layer, and that this fluid flow would eat away at the lower density material at the interface, thus raising the interface until a blend was obtained when the interface reached the surface of the liquid. The blending mechanism was found to be the same whether a top-entering mixer was used near the bottom of the tank as in the preliminary runs to explore the technique, or a side-entering propeller mixer was used near the bottom of the tank.

Figure 3 is a graph of the temperature changes in an experimental blending run in the 240-inch diameter tank. The mixing was accomplished with a side-entering propeller mixer.

Figure 4 is a graph taken from the literature (*4*), showing a blending operation in a stratified 20,000-barrel tank in which four charges of furnace oil of different API gravities were blended. In this case, the progress of the blend was determined by taking oil samples at various levels, determining the API gravity of the samples and plotting them against time. The temperature profile obtained in Figure 3 indicates that the same type of blending mechanism is obtained as was the case in Figure 4. It was concluded that the hot and cold layer technique using thermocouple probes would be a satisfactory method of measuring blending times.

In the experimental data reported here, the hot fluid was either 10% or 20% of the total. In studying any particular variable the proportion was kept constant. Experimental studies on the effect of this ratio indicated no detectable difference for these two percentages of hot fluid. Qualitative observations on higher percentages of the hot layer indicated that 50% of the total was the most difficult case.

PROCEDURE

To make a blending run, the following steps were taken:

a. The cold fluid was pumped into the tank to the desired depth.

b. The mixer was started and the desired rotational speed was set. The mixer was then stopped and the cold fluid was allowed to come to rest.

c. The layer of hot fluid was pumped into the tank using a float to prevent mixing at the interface.

d. The thermocouple recorder was started so that fluid temperatures throughout the tank could be measured before mixing began. The thermocouple recorder was then stopped.

e. The mixer and thermocouple recorder were started simultaneously.

f. The blend was allowed to proceed until temperatures throughout the tank reached an equilibrium value.

g. The length of the thermocouple recording chart between start of the mixer and the accomplishment of a blend was measured. Knowing the chart speed, this chart length was converted to a blending time.

VARIABLES

The variables studied in this investigation were:

a. Hot and cold layer temperature, and therefore the physical properties of the fluids.

b. Impeller diameter and impeller speed. These properties also varied the impeller horsepower input and D/T ratio.

c. Ratio of liquid depth to tank diameter.

d. Number of mixers and position of mixers on the tank periphery, including angle of entry.

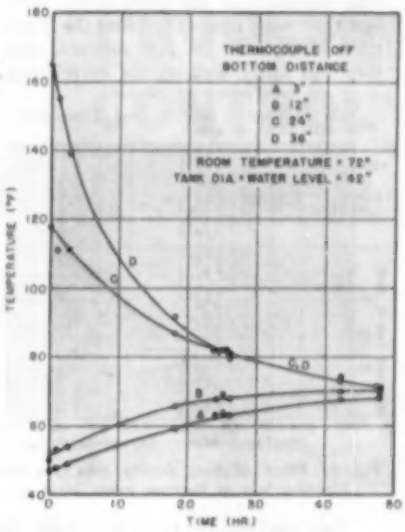

Fig. 2. Temperature changes in a stratified tank with no mechanical agitation.

Details of Experimental Results

EFFECT OF DENSITY DIFFERENCE

The first variable studied was the blending time at constant horsepower as a function of fluid density differences.

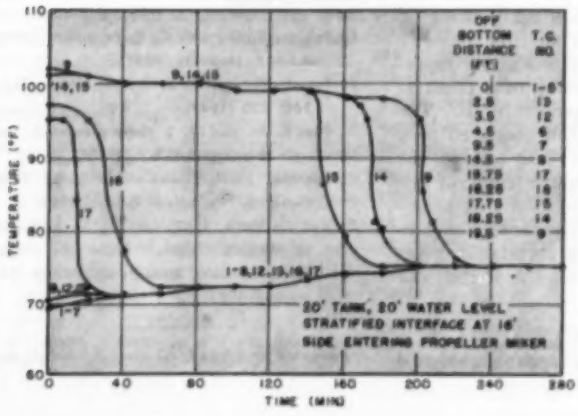

Fig. 3. Progress of blending in a 20-ft. diam. tank.

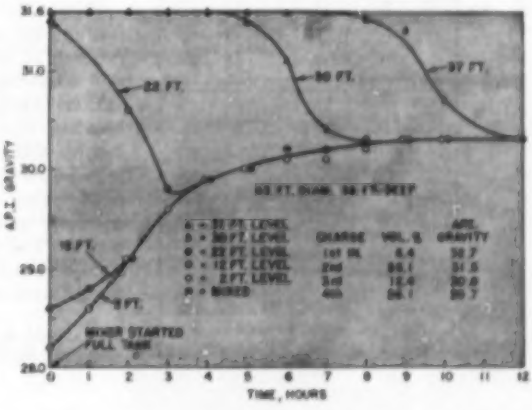

Fig. 4. Progress of blending in petroleum refinery tank (*4*).

A correlation was obtained by plotting blending time against the fractional density difference, $\Delta\rho/\rho_o$, on log-log paper, as shown in Figure 5. A slope of 0.9 was obtained. In order to extend the density difference further than could be done with hot and cold water, salt was dissolved in the cold layer. The squares on the figure represent the three runs made with the salt solution, and they fall fairly well on the correlating line. This slope of 0.9 was also obtained with different diameter impellers in other tank sizes. It was not possible with the particular method of obtaining warm water to obtain the same density difference in each run accurately. All subsequent data are corrected to $\Delta\rho/\rho_o = 0.02$. This correction takes the form

$$\theta_o = \theta\left(\frac{0.02}{\Delta\rho/\rho_o}\right)^{0.9}$$

where θ_o is the blending time used in the correlations, and θ is the actual blending time at whatever $\Delta\rho/\rho_o$ was used in the run. The density difference of 0.02 was chosen because it represents an average figure when blending tetraethyl lead into gasoline.

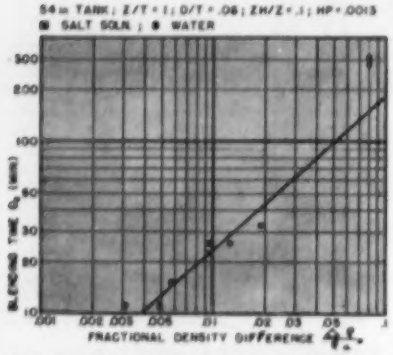
54 in. TANK; Z/T = 1; D/T = .06; Zh/Z = .1; HP = .0013
■ SALT SOLN.; ● WATER
BLENDING TIME θ_o (MIN.)
FRACTIONAL DENSITY DIFFERENCE $\frac{\Delta\rho}{\rho_o}$

Fig. 5. Effect of fluid density difference on blending time at constant power input.

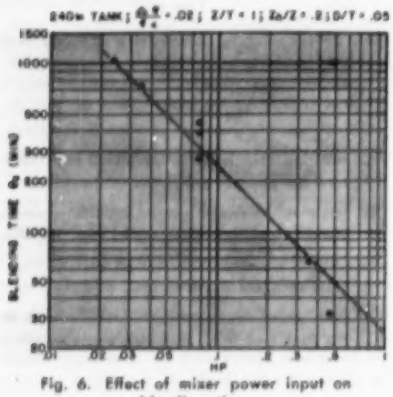

Fig. 6. Effect of mixer power input on blending time.

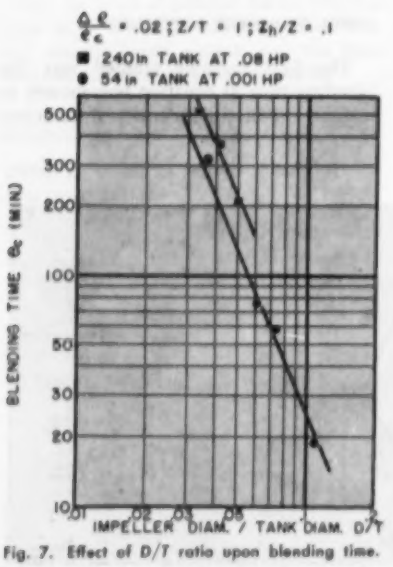

Fig. 7. Effect of D/T ratio upon blending time.

Table 1.—Effect of Mixer Entry Angle on Blending Time, θ_o

$\Delta\rho/\rho_o = 0.02$ | $T = 54$ in.
Horsepower = 0.0011 | $Z = 54$ in.
$D/T = 0.06$ | $Z_h/Z = 0.1$

Angle up from horizontal	Angle to left of diameter			Angle to right of diameter	
	20°	10°	0°	10°	20°
10°			124 min.		
5°			...		
0°	195 min.	77.5 min.	105 "	235 min.	284 min.
−5°			155 "		
−10°			144 "		

EFFECT OF HORSEPOWER ON BLENDING TIME

Since standard propellers of known characteristics were used, the speed could be translated to power input to the liquid. Figure 6 shows a correlation of blending time vs. horsepower in the 240-inch tank. This correlation has a slope of −1, and indicates that for a given liquid system and impeller diameter, the total energy for blending is constant. Again, a similar slope was obtained with other impellers and other tank sizes when all other variables were held constant except impeller speed.

EFFECT OF D/T

Figure 7 shows the effect of changing the impeller diameter to tank diameter ratio. The points on this curve represent an average of many runs taken at various $\Delta\rho/\rho_o$ and power levels. The blending time was then corrected to a density difference of 0.02 and to the horsepower listed on the right of the figure using the correlation that blending time was inversely proportional to power. The resulting correlation gives a slope of −2.3 for both the 54-inch and the 240-inch tank.

It should be pointed out that this slope held only for a square batch in which the liquid level was equal to the tank diameter. With decreasing liquid level, this slope decreased. This correlation indicates that increasing the pumping capacity of the impeller aids the blending operation.

EFFECT OF MIXER POSITION

Most of the experimental work performed was done with the mixer shaft making an angle 7° to 10° to the left of the diameter. However, a few runs were performed in which this position was changed. Table 1 shows that this position is near the optimum since blending time increases as the position is changed from the optimum.

Notation

D = impeller diameter
HP = horsepower into liquid
T = tank diameter
Z = total liquid level
Z_h = level of hot liquid
ρ_c = density of cold layer
ρ_h = density of hot layer
$\Delta\rho$ = difference in density between hot and cold layer
$\frac{\Delta\rho}{\rho_o} = \frac{\rho_c - \rho_h}{\rho_c}$ = fractional density difference
θ = blending time (min.)
θ_o = blending time (min.) corrected to $\Delta\rho/\rho_o = 0.02$
β = angle of mixer from tank diameter drawn at point of shaft entry

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Presented at A.I.Ch.E. meeting, Pittsburgh, Pa.

applications of ELECTRONIC PROCESS CONTROL INSTRUMENTATION

Extensive development work has been undertaken over the past several years which has resulted in relatively complete electronic process control systems which are available for complete refinery, chemical, and utility industries. Development of these electronic process control systems has opened up new fields of instrumentation to instrument and process engineers. Through the use of compatible electronic computer, calculating, automatic monitoring, scanning, and printing devices, process design engineers may now augment their applications of known techniques toward the goal of completely automatic process units.

H. J. Ruston * | Manning, Maxwell & Moore, Inc.
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While instrument manufacturers have at their disposal a vast instrumentation knowledge, their actual process knowledge is rarely equivalent to that of the users. Consequently, the full advantages which are now possible through the use of electrical instrumentation can be obtained only through close cooperation between user and instrument manufacturer. Several unique instrument applications have already been made.

One reason for the increasing popularity of the new electronic process control systems is their ability to solve unusual process control problems. Their use of electrical circuitry, which can be altered almost at will, makes for greater ease of experimentation and trial of new ideas. And, because various combinations and arrangements of vacuum tubes, capacitors, resistors, and other electrical components can furnish an infinity of signal outputs, new horizons are opened for the solution of processing problems that have heretofore defied the instrument engineer.

Obviously, most of the applications to which these devices have been applied have been to known types of control actions, duplicating in most cases the type of control function currently available in pneumatic instrumentation. However, knowing that the electrical techniques would provide practically limitless application possibilities, the American-Microsen process control system was designed to allow utmost flexibility for application.

Process Control Loop

Figure 1 shows a typical process control loop, with a transmitter, recording or indicating set station with the dual purpose of measuring the output of the transmitter and of introducing the set point or desired value of the variable to the control loop. This device also determines the error or difference between this desired value and the actual transmitted signal. Next in line in the control loop is the controller proper, which acts on this error signal to provide a controller output signal which is a combination of the various different control actions. The controller output signal flows through a measuring meter in the manual control unit, providing a valve position indication. The manual control also contains means of switching the control system from automatic to manual operation. The control loop instrumentation is completed at the valve through an electrohydraulic power device, or an electro-pneumatic relaying and positioning device.

The individual instruments in the control system are interconnected by wires. Rather than unitize the construction of the equipment completely, different functions have been assembled on individual building blocks; complete flexibility of the equipment is then achieved through different interconnection of these building blocks.

However, in order to achieve this flexibility, it was found necessary to choose a common signal, both for transmission from the measuring device to the control equipment, and for the signal carrying the instructions of the controller out to the valve operating device. In addition, it was obvious that, to match the adaptability of analog computing devices, a direct current signal was the most efficient type. This equipment consequently was designed with a compatible DC signal of ½ to 5 milliamperes, self-regulated so that it was independent of output load up to a maximum limitation of 3,000 ohms. With these design considerations, it was found that control functions could be interconnected in a variety of different ways, and that cascading of several control circuits was possible with a minimum of additional units.

Cascade Control System

The most common form of inter-connection between two control systems is probably that shown in the simple cascade control system in Figure 2. In this application, a compressor is withdrawing gas from a fractionator reflux accumulator, which, in turn, receives its gas and liquid product from the overhead of a fractionating tower. The control problem is to maintain fractionator pressure constant. This is done by controlling the steam to the compressor turbine. The fractionator pressure transmitter and its controller provide a control output which constitutes the set point of a secondary slave controller.

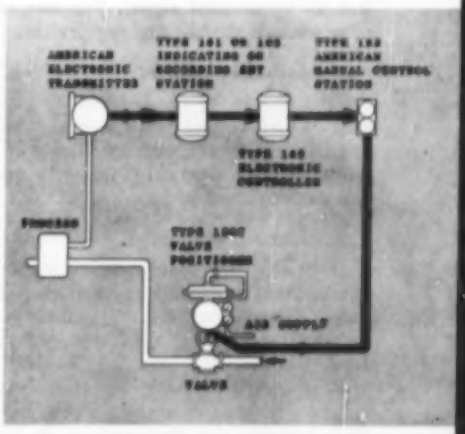
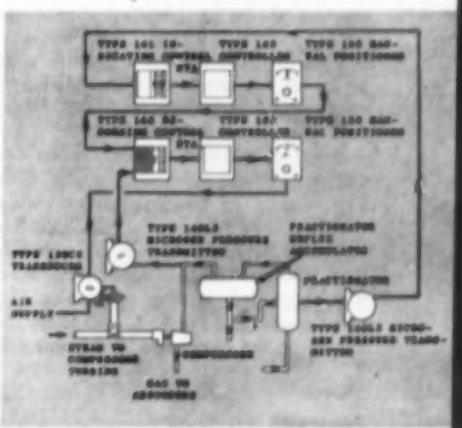


Fig. 1. Typical American-Microsen control system.

Fig. 2. Simple cascade control system.



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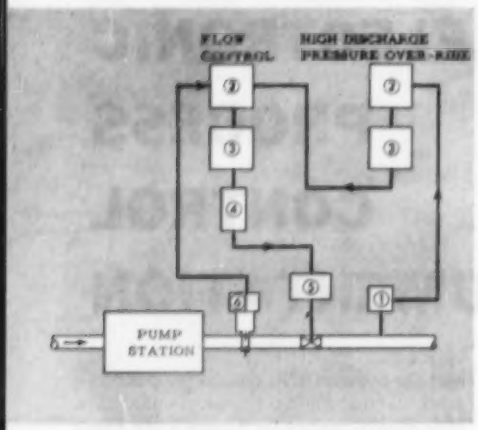

Fig. 3. Control set-up for discharge pressure limiting action. Figures represent control instruments as follows: 1) pressure transmitter; 2) recording set station; 3) controller; 4) manual control station; 5) electro-hydraulic valve operator; 6) electronic transmitter for differential pressure measurement; 7) electronic receiving indicator dial.

This slave controller, with its transmitter on the inlet to the compressor, acts as a very fast slave control system to compensate for steam pressure changes in the steam line to the compressor. Since output signal is on a span equivalent to transmitted signal, this can be done without signal matching devices.

Pipe Line Instrumentation

From the above simple standard version of two control systems in cascade can be built up the instrumentation requirements for a typical pipe line pumping station.

CONTROLLED-FLOW STATIONS

In certain pipe line pumping station operations (specifically in product pipe line stations) there are applications requiring the control of the discharge flow from the pumping station. Obviously, with a constant flow being maintained by the throttling of a valve in the line, it is possible for the pressure in the discharge of the pipe line station to exceed safe limits. Consequently, instrumentation must be provided to override the normal operating flow control and cause the valve to close down slightly so that the discharge pressure cannot exceed the maximum safe limit.

This is accomplished with the same pieces of equipment as those used in a conventional cascade control loop. Slight differences in external wiring and interconnection of the instruments effect this discharge pressure limiting action. (See Figure 3). In this application, when the discharge pressure of the pipe line is below its limit, and is consequently in a safe operating zone, the flow is being controlled at the mechanical set point position of the flow controller. The output of the discharge limit control is zero. When the discharge pressure rises to the mechanical set point on the discharge set station, the output of the discharge controller increases above zero. Being fed to the flow set point unit this output subtracts from the mechanical set point of the flow control to reduce flow. In effect, since flow is reduced, discharge pressure is held to its limit value. Later, when downstream operating conditions change so that the discharge pressure falls below its limit, the discharge control output returns to zero. The flow control then operates at its mechanical set point as before.

NON CONTROLLED-FLOW STATIONS

In other conventional pumping stations, the flow is not controlled. In these stations, the control valve in the station itself is normally held in a fully open position. If the valve is throttled to any extent, power is obviously being wasted. Control requirements therefore demand that the valve in the pumping station be kept wide open at all times so long as the discharge pressure does not exceed a safe upper limit, and the suction pressure to the pumping station does not drop below a safe limit for the pipe line. Appropriate electronic instrumentation for this type of limiting action again consists of two individual interconnected control systems as shown in Figure 4.

The discharge pressure limit is set on the discharge recording set station and the suction pressure limit is set on its recording set station. In normal operation, the suction pressure is above its limit set point and the discharge pressure is below its limit set point. The station control valve is fully open. In the system shown, the discharge controller is direct-acting. With reset action in the controller and with the discharge pressure below its set point, the controller output is zero. As soon as the discharge pressure rises to its set point, the control output current starts to increase in a positive direction. With an "increasing current to close" valve operator, the valve is throttled to maintain the discharge pressure at its set point.

Operation of the suction pressure control is similar. With the suction pressure above its set point and a reverse-acting suction pressure controller, the suction pressure control output is zero. As suction pressure drops to its set point, the control output current is increased, and the valve is partially closed. With low suction pressure, the valve will throttle to maintain suction pressure at its set point.

When abnormal suction or discharge pressure is overcome and the system returns to the normal operating condition, the valve is opened wide again.

SET POINT PROGRAMMING

In addition to suction and discharge overriding control, with or without continuous valve throttling to maintain flow, an additional type of control action is often desirable in pipe line pumping station operation. When a portion of a pipe line is placed in service and the pumping station is started up, it is quite often necessary to limit the rate of opening of a discharge control valve so that no sudden pressure surges are introduced into the pipe line. Sudden opening of a discharge valve after a pump has been placed on stream will, of course, cause a sudden pressure surge in the pipe line and could cause serious damage downstream from the pumping station. Consequently, automatic controls must be provided so that, when the station is started up, the discharge control valve will open very slowly until normal operating conditions are reached.

The addition of very minor electrical components to a standard process control loop (Figure 1) can accomplish set point programming without the addition of expensive equipment. As shown in Figure 5, the additional equipment required consists of only one condenser, two resistors and a relay with its contact. This equipment is inserted in the control loop between the output of the set point error detector and the input to the controller.

The object of this system can be stated as follows:

The discharge pressure must be brought under control in such a way that the controller acts initially to hold the discharge pressure where it was prior to the moment the controller was actuated. The discharge pressure is then brought under control and the valve opened in such a manner that the discharge pressure automatically approaches the value indicated by the mechanical set point lever in an exponential curve.

The system operates as follows:

Prior to the start of automatic control, the discharge pressure is generally below the value indicated by the set point lever of the discharge pressure controller. The relay is energized. The error signal from the set point unit in the system produces a voltage, most of which appears across the condenser C because resistor $R1$ is much larger than $R2$.

When the station is started up the relay is de-energized. The controller then acts to keep its input error $E2$ small, thus preserving the set point output error $E1$ until the condenser charge slowly dissipates through $R1$.

The rate at which this set point changes diminishes gradually, starting at a rate which would correct this error in T minutes. This error would be reduced to 1/50 of its original value in $4T$ minutes.

Consequently, as this condenser charge is dissipated, the controller gradually opens the valve at a rate equivalent to the rate of discharge of the condenser. This value of T is adjustable from 1/10 min. to 10

min. by adjusting *R*1. When all of the charge on the condenser has been dissipated, the discharge pressure is being controlled at the value on the mechanical set point index.

For the sake of simplicity, this system has been described as associated with a single control system. Obviously it can be, and is, applied in conjunction with both suction and discharge limit controls or automatic floating flow control with discharge or suction override. Automatic station shutdown devices have also been added by introducing on-off control relays operating on the transmitted signals in series with the controls.

Compensated Gas Flow Measurements

The ability of electrical instrumentation and measurement to perform difficult computations and its practical application in the process industries was recently demonstrated by an installation in an operating acetylene plant. The volume of acetylene gas product was being measured by a Roots-Connersville volumetric displacement meter, a mechanical device supplying a visible indication of flow on a cyclometer dial. The problem which faced the operating company was that this flow indication was entirely uncompensated for normal operating gas temperature and pressure. Since the standard volume of a flowing gas at standard temperature and pressure is directly proportional to pressure, and inversely proportional to temperature, this uncompensated flow value was essentially useless for plant performance calculations. Furthermore, to perform these two multiplications in a mechanical system requires complicated and expensive mechanical linkages and, for all practical purposes, is quite unsatisfactory from both cost and operating standpoints.

However, when handled electrically, the problem becomes quite simple. As shown in Figure 6, the volumetric flow meter is fitted with a DC generating tachometer. The voltage output of the tachometer, when connected in series through a resistance bulb (to measure the temperature of the flowing gas) and the input circuit of a computing device, produces a current in the circuit which depends on both the rate of flow of gas through the meter and the resistance of the resistance bulb measuring the temperature of the gas. As the flow through the meter increases, the voltage from the tachometer increases linearly. As the temperature of the gas medium increases, the bulb resistance increases and the current through the circuit decreases proportionally. In this way, a current value is obtained proportional to volumetric flow corrected for operating temperature.

In order to calculate the corrected flow value, it is necessary to combine the actual flow reading corrected for temperature changes with the ratio of actual pressure to standard pressure. To obtain the pressure correction, the pressure of the gas is measured on an absolute basis. To obtain the greatest accuracy, one transmitter is used to measure the actual flow pressure. The output of this transmitter is then corrected by a second transmitter output which is calibrated to act as a barometer. This barometer transmitter accurately pulses any ambient atmospheric pressure changes and corrects the output of the measuring transmitter accordingly.

The device which performs the final multiplication of the flow reading corrected for temperature, and the pressure signal is known as a Type 151 Computer. This instrument operates on the basis of Ohm's Law (the voltage across a resistance is equal to the current through the resistance multiplied by the resistance). The current signal, which is equivalent to flow corrected for temperature, passes through a resistance which can be varied. The signal, which is the ratio of actual absolute pressure to standard absolute pressure, flows through a servo circuit which varies the resistance in accordance with this pressure ratio. The voltage which appears across this resistance will then be equivalent to the product of the flow corrected for temperature and the pressure ratio. This voltage signal is then used in a conventional Microsen amplifier circuit to provide an output current signal with a span of ½ to 5 milliamperes, proportional to the volumetric flow corrected for both temperature and pressure.

In this application, the corrected flow reading is transmitted to several points in the plant, on two different recorders and one indicator. Since the acetylene product flow is the most important measurement being taken in the plant, many people are obviously interested in its value at all times. With a simple DC series circuit, this value can be made available at any required location.

The solution of this problem was accomplished using standard instruments throughout with the exception that the computer itself was a slight modification of a standard Recording Set Station.

Summary

These few instances in which the principles of electrical control have been applied only scratch the surface in showing the versatility of electrical process instrumentation. Many different control actions can be obtained simply through the variety of hookups of basic components. Obviously, many more complicated control situations will arise which can use even better the versatility of electrical instrumentation; manufacturers of this equipment await only the definitions of the problems by users.

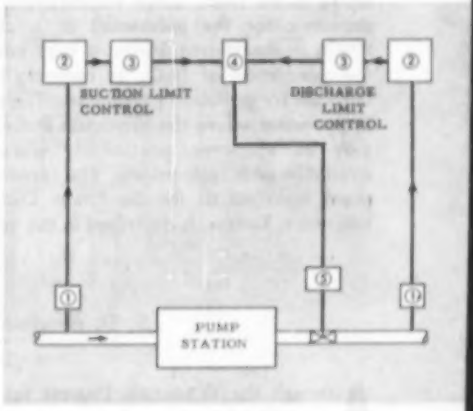

Fig. 4. Control set-up for pumping station discharge valve control. (See caption Figure 3 for instrument identification by number.)

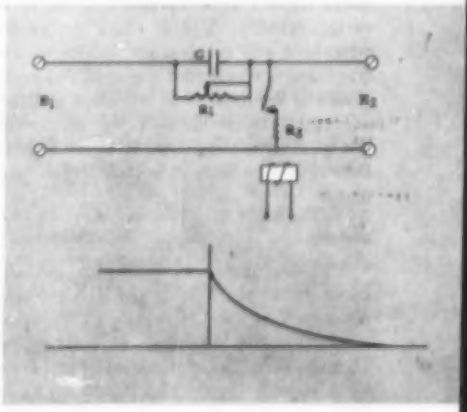

Fig. 5. Electronic control set-up for set-point programming.

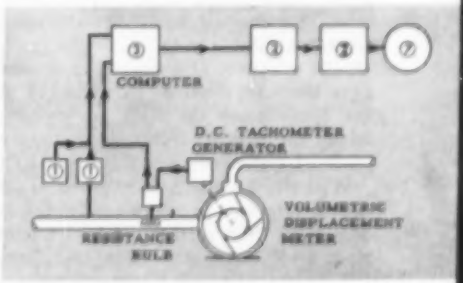

Fig. 6. Control set-up for compensated gas flow measurements. (See caption Figure 3 for instrument identification.)

WISCONSIN PROCESS SYSTEM

for recovery of DILUTE OXIDES OF NITROGEN

The Wisconsin Process was proven technically as a means for producing nitric acid, and the recovery system operated in accordance with design, except for minor modifications made in the field. Since the recovery system is not quite economic for the production of a cheap chemical like HNO_3 in the United States, it may have eventual use for the production of N_2O_4 or recovery of dilute oxides of nitrogen for pollution prevention. There may still be areas in the world where the Wisconsin Process, as it now stands, may be economic, particularly where ammonia is not available or is high priced. The recovery operation of the plant installed at the Sunflower Ordnance Works near Lawrence, Kansas, is described in the accompanying article.

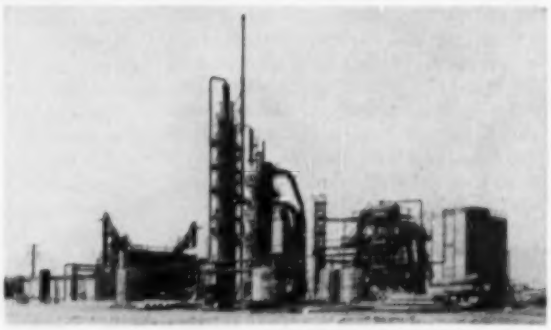

Fig. 2. General view recovery area.

E. D. Ermenc | Food Machinery and Chemical Corporation, Princeton, New Jersey

Although the Wisconsin Process furnace has been described in a previous article (*5*), the silica gel recovery system was only mentioned. The recovery of dilute oxides of nitrogen has been of interest since the old electric arc furnaces started to be operated at the turn of the century. Use of silica gel as an adsorbent and catalyst for oxides of nitrogen is not new, but the application of shallow, fluidized beds of silica gel for adsorption is unique as is the successful use of silica gel as a catalyst for oxidation of NO to NO_2 in a commercial size plant.

History

The original work on silica gel adsorption for the Wisconsin Process was conducted at the University of Wisconsin under the direction of Farrington Daniels (*6*). Prior work had been done by Almquist, Gaddy and Braham (*1*) in 1925, in which they had spelled out the requirements for operation of a silica gel system, but the electric arc process was on the decline and ammonia oxidation plants were taking over. After small-scale Wisconsin Process furnaces demonstrated their ability to produce oxides of nitrogen, Daniels and associates gave their attention to the recovery of the dilute gases via silica gel and obtained the data to design and patent a recovery system based on fixed beds (*4*).

With the transfer of responsibility for the development program to Food Machinery in 1946, further work on a pilot plant scale was begun under the direction of P. C. Wilbur, vice-president and research director. Food Machinery evolved the idea of fluidized beds to place the process on a continuous basis; this idea was patented (*8*). A pilot plant was constructed which used multiple-plate columns with shallow fluidized beds, and the necessary mass transfer data and physical and chemical data were obtained to design a large scale plant. Catalytic oxidation of nitric oxide through the use of silica gel and carbon was studied; silica gel was selected due to the danger of fire with carbon and adsorbed N_2O_4.

Chemistry and Kinetics

The oxidation reaction of nitric oxide has been studied at considerable length and is well known. Briefly the oxidation of nitric oxide is an inverse temperature reaction, the reaction being favored by lowered temperature:

$$2NO + O_2 \rightarrow 2NO_2$$

The reaction is exothermic, liberating 24,250 B.t.u./lb. mole and is quite slow. With respect to the kinetics, the reaction is of third order:

$$-\frac{dp_{NO}}{dt} = k(p_{NO})^2 P_{o_2}$$

The reaction rate constants are well known with the latest data, determined by Rao and Hougen (*9*) somewhat higher than those determined by Hasche and Patrick (*7*) and Bodenstein (*3*).

The homogenous reaction takes considerable time to obtain a 95% oxidation level at atmospheric pressure. Pressure favors the reaction, but essentially atmospheric pressure operation was used in the Wisconsin Process. Hence, means of promoting the reaction other than by pressure was necessary. The large volume of dilute gas to be handled precluded pressure operation because of the high cost of compression. Fortunately the reaction can be catalyzed by silica gel at a rate many fold greater than the straight homogenous reaction. Baker, Wong and Hougen (*2*) had done work in this field which proved helpful.

The NO_2 formed in turn polymerizes to N_2O_4, dependent upon temperature and pressure conditions:

$$2NO_2 = N_2O_4$$

The reaction is exothermic, liberating 24,700 B.t.u./lb. mole when N_2O_4 is formed. The equilibrium constants for the reaction are available, the ratio of the two components being readily calculated.

Reactions that take place in the acid tower include the two reactions enumerated above plus the formation of nitric acid:

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$
$$2NO + O_2 \rightarrow 2NO_2$$
$$2NO_2 = N_2O_4$$

A mixture of NO_2 and N_2O_4 is passed to the acid tower where the acid is formed. The partial pressure equivalent of NO_2 in the gas entering the acid tower of the Wisconsin Process is about

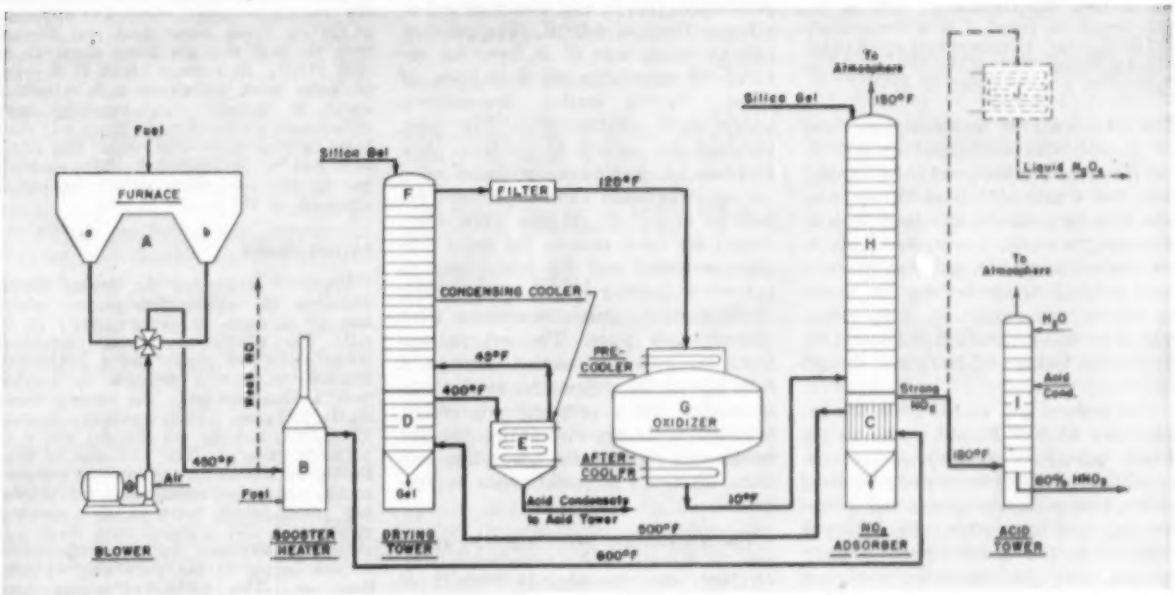

Fig. 1. The Wisconsin Process.

equal to the partial pressure equivalent of the gas in the Ammonia Oxidation Process, although the two processes operate at essentially atmospheric and 6 to 7 atm. pressure, respectively. The NO, resulting from the reaction of the NO_2 with water to form nitric acid, must be reoxidized and sufficient space must be provided to accomplish this reaction. For calculation purposes the N_2O_4 is considered to be inert, requiring reversion to NO_2 before entering the reaction, as outlined by Wenner (*10*). This may not be theoretically true, but the resulting absorber design agrees satisfactorily with actual operation. Equilibrium data are readily available for the nitric acid reaction.

Process

A flow sheet of the process is shown in Figure 1.

The furnace effluent gas passes through a booster heater, (B), to provide sufficient uniform heat for purging the NO_2 from the silica gel in the indirect-heated regeneration section, (C), of the NO_2 adsorber. The hot gas continues to the direct-heated regenerator section, (D), of the drying tower where water is stripped from the downcoming gel. The water in the still hot gas is condensed in the condensing cooler, (E), and the cooled gas continues through the water adsorber section, (F), of the drying tower, where water from the process gas is removed by adsorption on silica gel. The low dewpoint gas (−60° F. D.P.) is filtered to remove traces of silica gel dust and cooled. After precooling, it is then passed through the oxidizer, (G), where the NO is catalytically oxidized to NO_2. (Low dewpoint gas is required for the catalytic oxidation.) The NO_2 bearing gas is cooled to remove the heat generated by the oxidation reaction and to provide a low temperature of 10° F. before entry into the adsorption section, (H). As the gas passes through the tower, the countercurrently flowing silica gel removes the NO_2, and the stripped, dry process gas vents to atmosphere. In the regenerator, (C), of the NO_2 adsorber, heat has been provided by the process gas, as previously mentioned, and NO_2 is removed from the gel. A small amount of air is blown through the gel to help remove the NO_2. The NO_2 rich gas is cooled and blown to the acid tower, (I), where 60% HNO_3 is formed. Condensate from the condensing cooler, (E), consisting of 18 to 20% HNO_3, is pumped to the acid tower, (I), to provide the necessary absorbent for the NO_2. Air is introduced into the bottom of the acid tower to provide enough oxygen for the oxidation of NO to NO_2 and to purge the acid of any dissolved oxides. Depending upon the use to which the acid will be put, it may or may not be filtered before it is pumped to storage. Acid tower gas effluent may be returned to the adsorption system.

In case of need, as in start-up or trouble in the recovery section, a vent stack, provided to by-pass furnace gases to atmosphere, allows the furnace, (A), to keep operating when the recovery system is off stream. Conversely, in case of a short shutdown of the furnace, a by-pass is provided to keep the recovery section operating on air in readiness for resumption of furnace operation.

For production of liquid N_2O_4, a refrigerated cooler, (J), would be required after the regenerator section, (C), of the NO_2 adsorber and, to increase the concentration of NO_2—N_2O_4 in the rich gas, less purge air would be introduced. A pressure tank for storage and a cylinder and/or tank car filling station would complete the installation.

Equipment

Figure 2 is a photograph of the Sunflower plant. The booster heater was a standard unit, manufactured by Petro Chem Development Company, having a tube surface of 900 sq.ft. The process gas passed through the tubes, the flame being on the outside, with natural gas and fuel oil as the source of heat. Its function was to provide heat for regeneration of gel and to even out the fluctuations in temperature from the furnace.

REGENERATOR SECTION

The NO_x adsorber regeneration section was an indirect heated unit. The heat exchange tubes were 1-in. diam., with a surface area of 5,000 sq.ft. Flow of gel from the adsorber section was controlled by means of a grate installed below the tubes (see Figure 4.). A strong gas of 50% NO_x equivalent was produced, but higher concentration could be obtained by reducing purge air; for the production of nitric acid, a 50% NO_x gas was desired.

A gas containing 80% NO_2 equivalent was produced occasionally on start-up indicating that 90 to 95% NO_2 could be obtained for condensation of N_2O_4. At a concentration of 90% NO_2 equivalent, 95% of the NO_2 would be liquefied at a temperature of 15° F.; at a concentration of 95% NO_2 equivalent, 95% of the NO_2 would be liquefied at a temperature of 32° F.

The gel entered the regenerator at about 20° F. and was discharged at 400° F. Gel flow rate was designed to be 600 lb./min., but a rate of 400 to 450 lb./min. was actually used due to a bottleneck in the capacity of the downcomer pipes to the regenerator. The gel was given a final purging before leaving the vessel to remove any remaining NO_2, and a seal of gel was maintained in the exit leg to prevent leakage of NO_2 into the gel air lift.

The process gas exited from the regenerator at 500° F. and passed to the water adsorber regeneration section, consisting of five direct contact fluidized plates, four perforated plates and a bubble cap, gas entry plate. The gel was fluidized by the countercurrent passage of gas, and the water removed was picked up by the gas, which passed to the condensing cooler at 400° F. The gel entered the regenerator at a temperature of 50° F. and was removed at a temperature of 400° F. The gel flow rate at design was 80 lb./min. for removal of approximately 8 lb./min. of water. Spring loaded downcomers, which were constructed of 5-in. pipe, provided for passage of gel from plate to plate. A diaphragm, mounted on a spring, regulated the opening for passage of gel. If gel flow were interrupted for some reason, the metal diaphragm would seal the downcomer to prevent by-passing of gas. For the flow of 80 lb./min., four downcomers were provided per plate. The gel passage from the adsorber section through a 6-in. pipe to the regenerator section was controlled by a proportioning valve, actuated by the pressure drop across the bubble-cap plate of the adsorption section. This can be readily seen in Figure 3.

The 304 stainless steel condensing cooler was a fin-type unit, manufactured by McQuay, Inc. containing 53,000 sq.ft. of surface. It cooled the process gas from 400° F. to 45° F. and condensed a major portion of the water. Approximately 60% of the cooling area was water cooled, with the remainder refrigerated by ammonia at 30° F. Some nitric acid was formed here, the acid strength being about 18 to 20% HNO_3. In summer about 45 lb./min. of water were condensed and in winter about 30 lb./min. High-humidity days occasionally produced more dilute acid than could be used in the acid tower; this dilute acid had to be discarded. The entering gas to the condensing cooler was at a dewpoint of 98° F.

DRYING TOWER

Figure 3 illustrates the drying tower, including the regeneration section, which was 10 ft. diam. by approximately 70 ft. tall. The adsorption section, containing seven perforated plates and a bubble-cap entrance plate was designed to provide —60° F. dewpoint gas. The velocity based on the full cross section was approximately 4.5 ft./sec., and the gel charged was 6 to 12 mesh material. The unit was of steel throughout except for the entrance chamber to the adsorption section and the bubble-cap plate, which were of 304 stainless steel. Also, 304 stainless steel sheet was extended downward into the regenerator section owing to the possibility of condensation. The perforated plates were punched with 5/16-in diam. holes spaced to give an open area of 13% of the plate area. Plates were the same in all towers except for number of downcomers; plate efficiency was about 80-90% and, as in the regenerator section, four downcomers per perforated plate were provided.

In the original plant no filters were installed for silica gel dust removal, but even though dust losses were low, 1 to 3 lb./hr., it was considered certain that the fixed-bed oxidizer would plug eventually. Since no one relished the prospect of having to remove NO_2-laden gel, two filters were designed and installed in the field, with a glass fiber medium. The units were 5 ft. diameter by 10 ft. long with an internal perforated cylinder wrapped with a glass fiber mat and made of steel. Filter area amounted to 100 sq.ft./unit for removal of less than 1 gr./cu.ft. dust loading. Pressure drop, clean, was about 4 in. water, and the mats were cleaned or replaced when the pressure drop rose to 10-in. water. One unit remained on stream while the other was being cleaned.

OXIDIZER

The oxidizer was 22½ ft. diam., constructed of steel with 430 stainless steel lining the interior where it contacted gel. Silica gel bed depth was about 2 ft., the charge of gel of 6 to 12 mesh material totaling 30,000 lb. The unit was designed to convert 95% of the NO to NO_2. The low dewpoint gas of —60° F. was necessary for the oxidation step, low dewpoint being required for the silica gel to act as an efficient catalyst. Pilot plant data had indicated that a conversion of only 85%

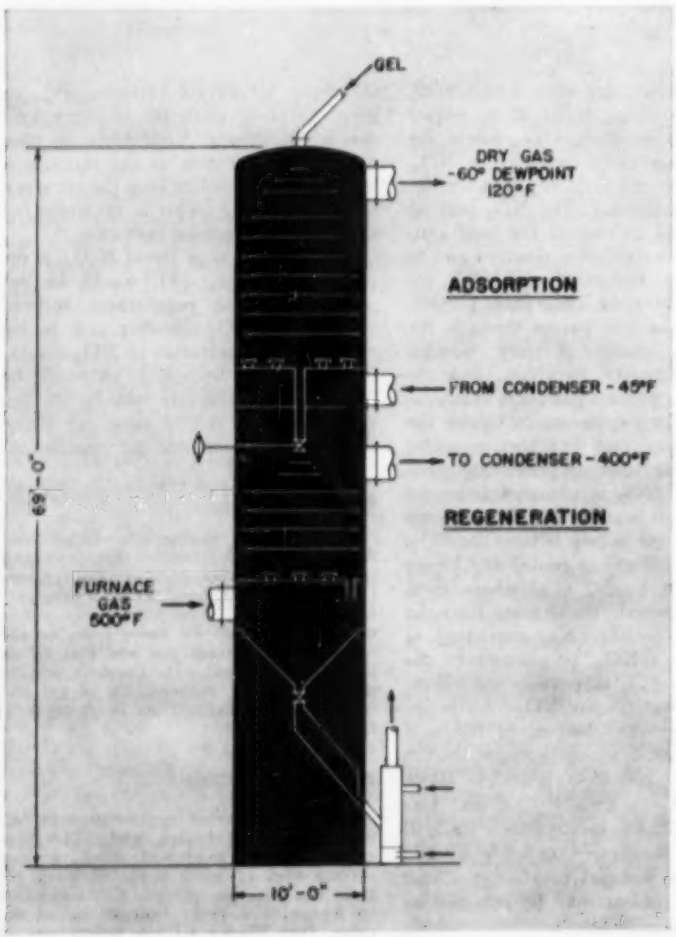

Fig. 3. Drying tower.

could be expected with a −20° F. dew-point. The gas from the drying tower was cooled to 60° F. via a refrigerated fin-tube exchanger before passing through the oxidizer. Velocity through the bed was 50 ft./min., based on the free cross section of the vessel.

After passing through the oxidizer, the gases were cooled again by a refrigerated fin-tube exchanger to a temperature of 10° F. before entry into the NO_2 adsorber section. The NO_2 adsorber, shown in Figure 4, was 10 ft. diam. by 92 ft. tall, including the regenerator. The adsorber contained twenty-one perforated plates and a bubble-cap entry plate, the perforated plates being of the same design as in the drying tower. However, the gel flow was designed for 600 lb./min., requiring twenty-four downcomers per plate instead of four provided in the drying tower. Gel entered the tower at 350° F. and exited to the regenerator at 15-20° F. Passage of gel between the adsorber and regenerator was through six 3-in. diam. pipes, which were kept filled with gel to prevent escape of NO_2 from the regenerator. The NO_2 adsorber was designed for a recovery efficiency of 95%, but with smooth operation efficiencies of 98% were obtained. Plate efficiency was of the order of 25 to 30%.

The air lifts on both towers were of the same design, the drying tower unit designed for a maximum of 200 lb./min. and the NO_2 adsorber unit for 800 lb./min. Conveying line sizes were 5 and 10-in. diam., respectively. The engagers consisted of a bubble-cap distributor plate and pipe annuli. Air flow was split with one portion passing through the bubble-cap plate to fluidize the incoming gel entering through one annulus, and the remaining portion entering through another annulus to pick up the fluidized gel and convey it through the main line to the top of the tower. Here the gel was released from the stream in a disengager section or plenum chamber, where the air velocity was reduced and the gel returned to the tower by gravity flow. Carrying velocity in the main line was 30 ft./sec.

The strong gas, 50% equivalent NO_2, from the regenerator section of the NO_2 tower was picked up by a blower and passed to the acid tower. The acid tower was of 304 stainless steel, containing eighteen bubble-cap absorption plates and two purge plates. The tower was 5 ft. diam., by 40 ft. tall, and was designed for an efficiency of 95% with entering gas at 95° F. Cooling coils were provided on each plate, total cooling surface area being 640 sq.ft. The cooling coils were spaced with maximum surface on the highest duty plate, which was absorber plate No. 6. Plate spacing varied from 1 to 2 ft., the first four absorbing plates having a 1-ft. spacing and the rest 2 ft. Acid of 60 to 65% strength was regularly made.

Gas velocity in the acid tower was about ¾ ft./sec., and the pressure drop about 2 lb./sq.in. Air was introduced below the purge plates to remove traces of NO_2 dissolved in the acid and to provide the additional oxygen necessary for oxidation of NO formed; about 75% excess air was utilized in the tower.

REFRIGERATION SYSTEM

The refrigeration system was a standard ammonia-absorption-type unit, rated at 630 tons of refrigeration. Low-pressure steam was obtained from the steam turbine driving the main blower.

A cooling tower was provided with a capacity for 40,000,000 B.t.u./hr.

Operational Notes

A number of changes were required in the recovery system to make continuous operation possible, the first major problem encountered being loss of silica gel. Heavy losses were first noted from the drying tower with attention first focused on losses after the regenerator section. On start-up, gel piled up in the plenum chamber below the condensing cooler. Originally the regenerator section contained perforated plates with 30% open area and a 1-in. static gel depth. The plates were changed to the same open area of 13% and 2-in. static gel depth as in the adsorber sections and 40% of the process gas by-passed. Losses were reduced to less than 1 lb./hr. through these modifications.

Losses from the adsorber section were also considerable at start-up; this fact made necessary minor modifications on the outlet of the tower to provide for more uniform withdrawal of process gas across the whole cross section of the tower. Addition of carbon also helped to reduce gel losses through dissipation of static charges which built up on the gel as a result of low dew-points involved. As a result gel losses were brought down to 1 to 3 lb./hr. with possibilities of further reduction.

Gel losses from the NO_2 tower were brought under control with the experience gained from the drying tower operation. Due to the greater gel cir-

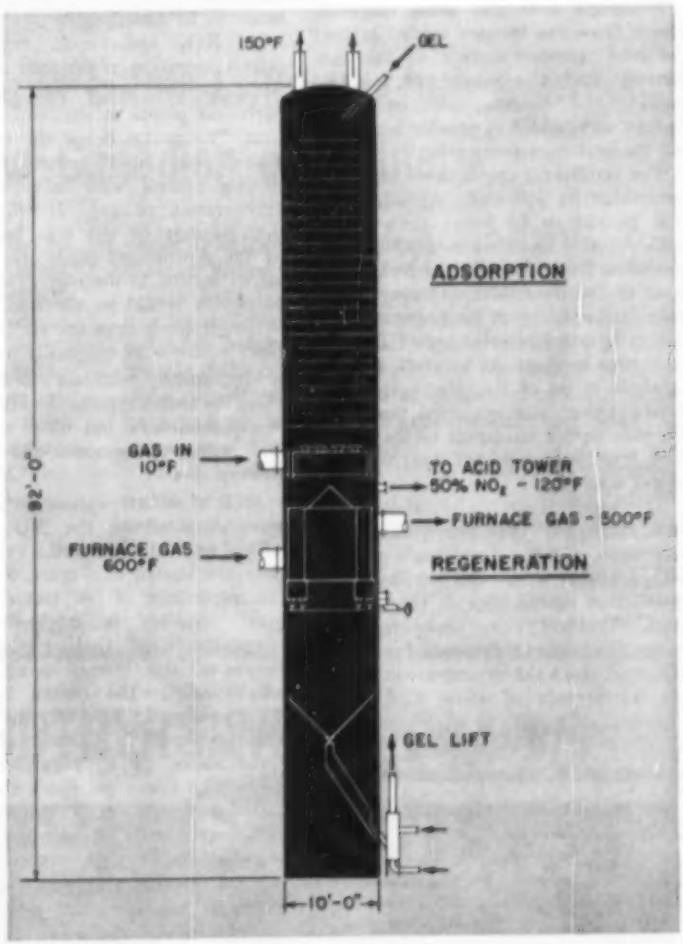

Fig. 4. NO_2 tower.

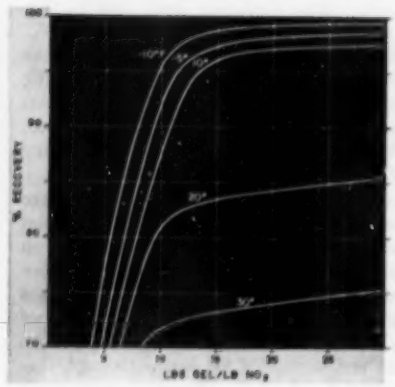

Fig. 5. NO_2 tower performance.

culation rate, losses were higher than in the drying tower; losses were reduced to the range of 10 to 12 lb./hr. with possibilities for further reduction visualized. To provide for the same exit gas volume space as in the drying tower, the two top plates were eliminated with no adverse effect on tower operation.

Silica gel dust plus some magnesia blown from the furnace tended to coat the heat transfer surface of the condensing cooler, resulting in eventual build-up of system pressure drop. Sprays were added to provide for washing the unit once every 8 hr.

The oxidizer gave little trouble and performed its job well. Actual operation proved to be better than design with the NO oxidized to a 97 to 98% oxidation level. However, the oxidation level of the input NO was also higher than design, being of the order of 70%; design figures had indicated an entering oxidation level of 30 to 40%, but the catalytic effect of the silica gel in the drying tower was neglected purposely. To provide for oxidation to the design 95% level, it is expected that 20,000 lb. of gel would have been adequate.

The material of construction of the heat exchanger after the oxidizer was aluminum, and the ducts leading to the NO_2 adsorber were steel, but any future installation should provide for stainless steel. Troubles were experienced occasionally with obtaining the design dewpoint from the drying tower due to the interference of nitric acid vapor.

Table 1.—Unit Requirements

Item	Unit/Ton 100% HNO_3
power	1,100/kw.-hr.
fuel	18,000,000 B.t.u.
water	2,700 gal.
silica gel	6 lb.
pebbles, 97% MgO	40 lb.
steam	nominal

Since the ammonia temperature in the oxidizer aftercooler ranged from −10° to −20° F., care had to be exercised against diverting dewpoints higher than −20° F. into the system to prevent condensation of acid. Actually dewpoints were held to a maximum of −30° F. before diverting gas into the oxidizer-NO_2 adsorption system. By the use of a stainless steel exchanger after the oxidizer and by the use of stainless steel for duct work to the NO_2 adsorber, including the bubble cap plate, little time would be lost on start-up. Sufficient gel was in the oxidizer to allow still for good efficiency even with the higher dewpoint. As operation continues after diversion of gases the dewpoint tends to lower. Further work is being done at the University of Wisconsin, under the auspices of the Wisconsin Alumni Research Foundation to define better the performance of gel under varying dewpoints.

Some trouble was experienced at the regenerator of the NO_2 adsorber where corrosion was experienced in the chamber above the tubes. Some moisture tends to be adsorbed on the gel along with NO_2 and, upon regeneration, causes corrosion in the area mentioned. Stainless steel sheet was installed at corrosion points to eliminate the problem. The grates below the tubes were altered from on-off control to proportioning control with better results on regeneration of gel. It was believed that passage of gel was bottlenecked by the downcomer pipes from the adsorber section to the regenerator, which bottleneck would be alleviated by more or larger pipes than the six 3-in. diam. pipes which were originally installed.

Mechanical problems were experienced to an uncommon degree with the original blowers, but these were rectified with replacements and modifications.

Most of the adsorption efficiency data were obtained on the NO_2 adsorber which worked very well. Performance data are shown in Figure 5 in which the importance of low temperature for good recovery is emphasized. The temperatures indicated are inlet gas temperatures, the towers being operated adiabatically. The design figure was 10° F. at a gel: NO_2 ratio of 14. Poor recovery would be indicated at temperatures above 10° F. regardless of gel flow. The lower gel flows used in the plant were combined with lower temperatures than 10° F. in order to obtain the good recovery experienced.

Little trouble was experienced with the acid tower, which operated well and close to the 95% recovery designed. However, the effluent gas did entrain some acid on occasions, and a light brown plume was evident. As a means of increasing recovery and reducing the small losses from the tower, the stack was tied back into the system before the condensing cooler. The only loss was then through the effluent stack from the NO_2 adsorber. The introduction of oxides of nitrogen from the acid tower at the condensing cooler resulted in an increase in the acid content of the condensate from 18 to 20% to 20 to 22%, but this presented no problem.

Once the initial start-up modifications had been made, the plant operated well and, with the knowledge gained, further improvements can be made. Work on gel losses was not considered complete, the best spot figures being of the order of 5 lb./ton 100% HNO_3. Pilot plant results had indicated an expected loss of 1.3 lb./ton 100% HNO_3, and it is reasonable to believe that further progress could be made.

Economics

The total cost of the nominal 40 tons/day equivalent 100% HNO_3 plant, including engineering and overhead, was slightly over $2,000,000 with about 60% of the cost in the recovery system; the major portion of the operating costs was also incurred in the recovery system. In relation to the conventional process for producing nitric acid, the Wisconsin Process is not quite competitive in the United States, and further work is continuing on other recovery systems to reduce costs.

The unit requirements for a Wisconsin Process plant including the furnace are shown in Table 1. These requirements assume all electric drives.

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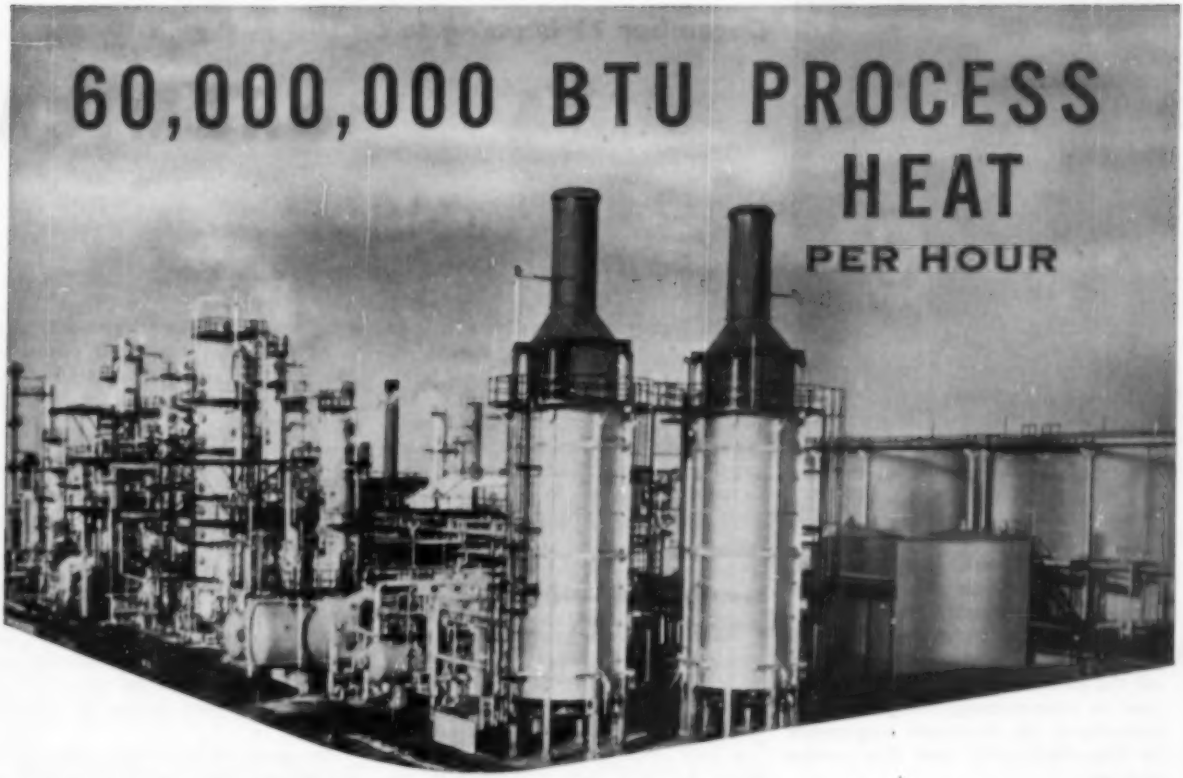

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December 11 will be Chemical Engineers' Day in the Commonwealth of Massachusetts by Gov. Christian Herter's November 16 proclamation which called upon all the people of the State to take part in recognizing the great contributions of chemical engineers to Massachusetts and the entire nation.

December 11 is going to be . . .

CHEMICAL

H. G. Taylor and G. F. Eline, Jr. | Esso Standard Oil Co.

With Massachusetts paying tribute to the chemical engineer, Boston, its capital city, will be playing host to members of the profession at A.I.Ch.E. Annual Meeting December 9-12. According to shape-up of final plans, the Boston meeting promises to be one of the most comprehensive, and in some ways the most unusual, in recent A.I.Ch.E. history.

Spotlight on Highlights

Sales management, sales engineers and would-be's, by all indications, are going to be able to air their latest ideas about "getting across to the buyer," as well as resolving some of the problems affecting both employee and employer. This is an A.I.Ch.E. first, and there is evidence not only that engineers are anxious to be there, but that their companies are just as anxious to send them. Should prove much meat for buyer as well as seller.

Interest is heightening in the special meeting on *oxygen plant mishaps* and what to do about them, which will follow the discussion of one of the most important General Session papers at the meeting, Safe Design and Operation of Low Temperature Air Separation Units, by F. G. Kerry, American Air Liquide. Latest word is that Earl Clark, Air Reduction, will chairman the discussion session to which only actual users and designers are invited to meet in a special room.

Arrangements have been completed for the unique Monday night *Roundtable on*

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. . . *in Massachusetts*

FOR YOUR CALENDAR

A.I.Ch.E. Annual Meeting

Boston, Massachusetts
December 9-12, 1956
Hotel Statler

Registration: Mezzanine Floor, Hotel Statler.
First technical session: 2:00 P.M. Monday
Last technical session: 2:00 P.M. Wednesday
Banquet: 7:00 P.M. Tuesday

Advancing the Automatic Control of Chemical Process Plants, where a special projector is being supplied so that the participating experts can draw their own diagrams for projection on a screen. Real audience participation is desired at this session, so come prepared to talk briefly, show your own slides or make drawings. Anyone interested in expressing a particular view is urged to contact W. D. Alexander, Monsanto, Texas City, Tex., or any of the participants listed in the meeting program (see *CEP*, October, 1956). Not required, of course, so just come and get up on your feet, but advance notice enables you to fit in your plans with others.

Rapid growth of the role of *the chemical engineer in the pulp and paper industry* is expected to attract a large turnout at the Pulp and Paper symposium. So rapidly is the industry expanding that its needs for the latest in chemical engineering innovations has become an issue. This is particularly true in the utilization of waste, in silvichemicals, and in other by-product areas, but it is also true in pulp and paper making itself, and the interests of the chemical industry and the pulp and paper industry are tending to merge. And it is the chemical engineer who is looked to for leadership into advanced processes and efficiencies. One crystal-ball feature of the symposium will be a description of the small-scale, large-output, continuous, high-speed mills of the future. These will probably be small enough to be semi-portable, will be hauled wherever the timber is cut.

Want some of the latest thinking about *automation of filtration units?* This will be only one of the attractions that will bring industry's engineers to Frank Tiller's symposium on filtration. One of the theoretical papers is going to provide a new basis for filtration calculations not presently covered in filtration literature.

The interest in *low temperature techniques* today is so widespread, the techniques are to be used by so many industries, that no engineer interested in the future can afford to overlook this session aimed at the design level.

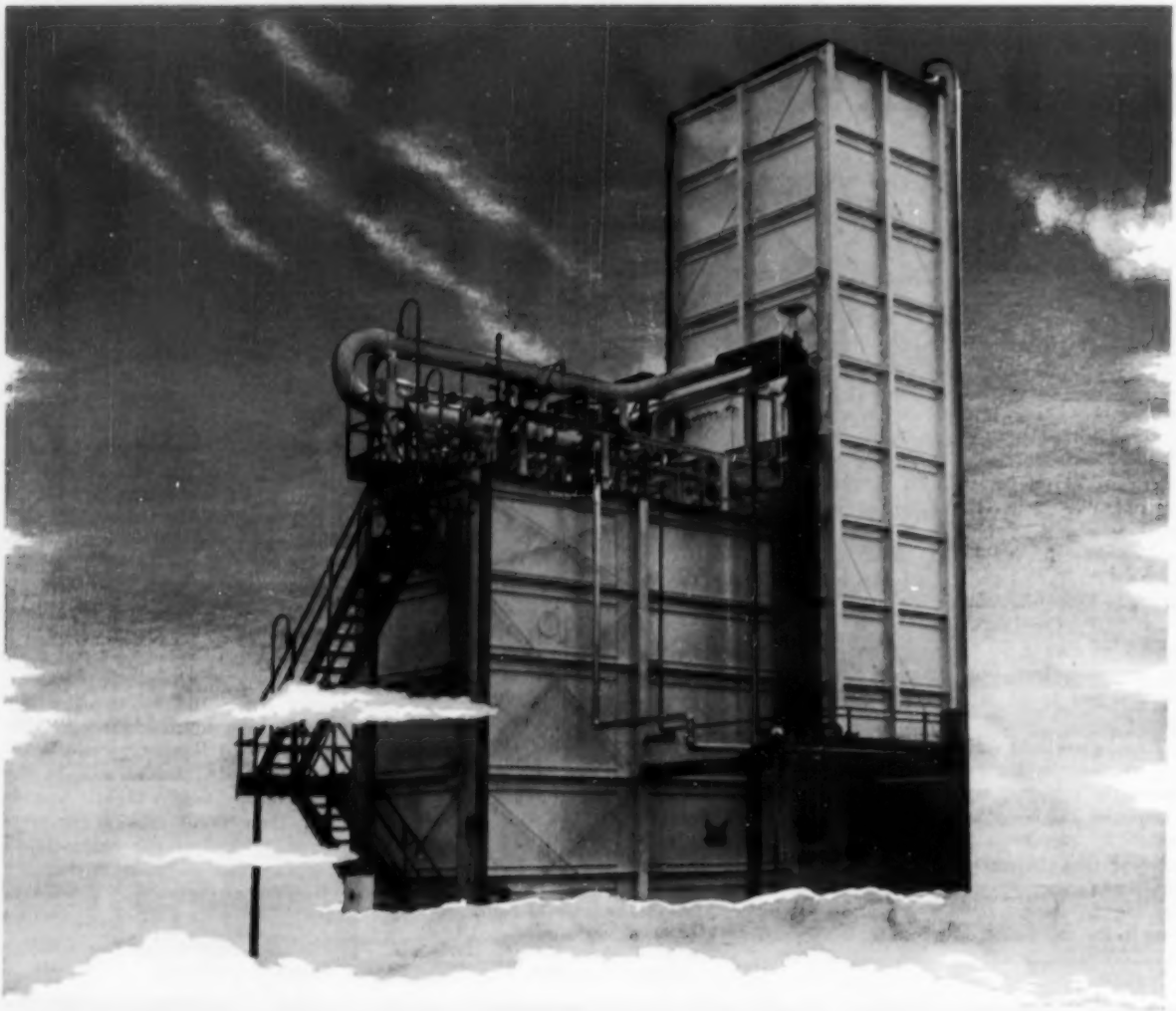
At a time when *training in nuclear energy* is a most vital field of consideration, with AEC footing the bill for new teaching aids up to a total of $3 million (see *CEP*, September, 1956), the facilities which the universities will be selecting should be of concern to every chemical engineer. Come and hear what has been used, what is being used, what may be used, and give your views.

Speakers and Awards

Dynamic, very much in the news, 55-year-old Chief of Naval Operations Admiral Ardleigh A. Burke will be the main speaker at Tuesday night's Awards Banquet. The Navy "runs on engineering" as we all know. The Admiral will have a vigorous story to tell of the role of chemical engineering technology

(*Continued on page* 50)

Boston Committee Chairmen on page 50



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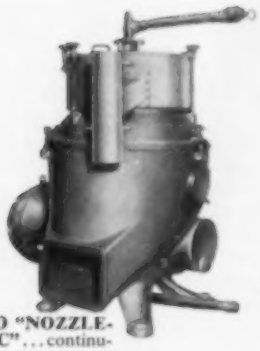

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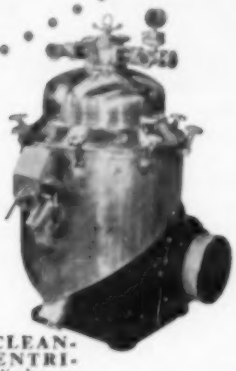

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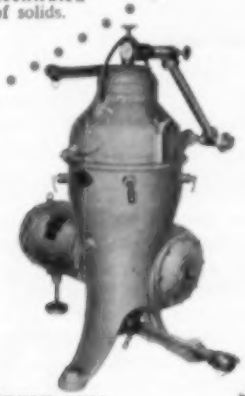
THE DE LAVAL SEPARATOR COMPANY Poughkeepsie, New York • 427 Randolph St., Chicago 6
DE LAVAL PACIFIC CO. 201 E. Millbrae Ave., Millbrae, Calif.



HERMETIC CENTRIFUGE . . . operates under positive pressure. Mixtures separated or clarified without agitation . . . no contact with or entrainment of air.

GYRO-TESTER . . . for laboratory and pilot plant . . . combining high speed test tube centrifuge . . . continuous, constant efficiency centrifuge . . . will break most emulsions readily . . . makes basic determinations with high accuracy.

MULTIPLE CLARIFIER . . . double-bowl construction. Effectively clarifies liquids with constant efficiency throughout entire run.

TYPE K CLARIFIER . . . handles high capacities of multiple clarification—up to 2,600 gallons per hour . . . solids holding space, over 17 gals.

Committee chairmen for the Boston Annual Meeting of A.I.Ch.E. are (l. to r.) third row: W. R. Pavelchek, Student Program; G. P. Taggart, General; J. E. Vivian, General Finance; J. P. Eames, Student Program; Richard Rome, Entertainment; L. P. Deakoff, Entertainment; Joseph Voci, Meetings Management; John W. Cross, Registration. Second row: W. Rousseau, Technical Program; H. Reynolds, General; R. K. Flitcraft, Program; P. Raymond, Hospitality; S. Zdonick, Plant Trips; R. Antonsen, General; F. O. Perry, Jr., Hotel; C. Angell, Finance; O. A. Randall, General. Front row: Ralph A. Troupe, Registration; James Donovan, General Chairman; Arthur Collins, Printing. Not shown in the photograph are: A. W. Fisher, Jr., Vice-General Chairman; Thomas G. Gibian, Hospitality; Graham B. Knight, Plant Trips; Alan Michaels, Student Program; Robert E. Siegfried, Sunday Symposium; Harry G. Taylor, Public Relations.

BOSTON MEETING

(*Continued from page 47*)

and developments in the Navy of the future.

Burke, known as "31-Knot" Burke in tribute to his daring destroyer tactics against the Japanese in World War II, is a "blue-water" sailor of the first order, but in addition he is also known as a man of high intellectual curiosity, an avid student of history and of the future, and a chemical engineer in his own right (he is a member of A.I.Ch.E.). Raised to the top Navy post from far down the flag list (Burke was a Rear Admiral when he was chosen last year to be top man over more than 90 admirals senior to himself), Burke will bring all his concern for the future, his breadth of experience in the highest levels of defense-applied engineering, to his presentation as banquet speaker.

The Awards Banquet will also be the time for A.I.Ch.E. to honor the winners of this year's awards. Representing the profession's acknowledgment of the unusual attainment of outstanding members, this year's awards go to:

R. R. White (*Professional Progress Award in Chemical Engineering*), University of Michigan, for his distinguished record in chemical engineering education and practice, and for his important contribution to the scientific approach to chemical engineering problems. White, an articulate leader of the basic engineering science approach to engineering education, cited a few years ago by *Fortune* as one of the nation's outstanding young men, will present his talk at 11:00 A. M. Tuesday. Subject: Chemical Engineering Unlimited.

E. W. Comings (*William H. Walker Award*), head of the School of Chemical and Metallurgical Engineering, Purdue University, for his many contributions to the chemical engineering literature, especially in the field of high pressure technology.

Theodore Weaver (*Junior Award*), Fluor Corp., for his paper on Economics of Acetylene by the Wulff Process, published in *CEP*, Vol. 49, page 35, 1953.

Ardleigh A. (31-Knot) Burke, 55-year-old Chief of Naval Operations, will be featured speaker at Tuesday night's Awards Banquet. A renowned "blue-water" sailor, Burke is a noted chemical engineer, a member of A.I.Ch.E., and will tell the assembled engineers of the role of chemical engineering in the Navy of the future.

Don't Overlook These

Among the special meetings will be a Monday session for those interested in the formation of a Heat Transfer Division. Steps necessary to such a formation will be discussed.

Then there will be the Tuesday annual meeting of the Nuclear Engineering Division.

The Annual Business Meeting is, as always, on Monday morning, at which time the Teller's Committee will break the news on the election of officers and directors. The treasurer and the secretary will report, as will all the committees.

Still another feature of this year's Annual Meeting is that the Institute Lecture will be delivered by W. K. (Doc) Lewis, MIT, on the always vital subject of Engineering as a Profession. Known never to miss an opportunity for colorful metaphor, his presentation of this subject will again be a delight to his former students and a never-to-be-forgotten experience for many other engineers. Remember the time—Monday at 9:30 A. M.

And don't forget to make early plans for the President's Luncheon on Monday to hear Walt Whitman discuss current and future plans of the Institute.

Committees—The Working Force

The backbone of Institute operations is the committee—all the committees. The Annual Meeting is the place where they meet to report and discuss, and where members can sit in and find out what is being done by the committee or committees in their own particular field of interest. Consult your program for time and place, or just chat with the committee chairmen as you recognize them at the mixer.

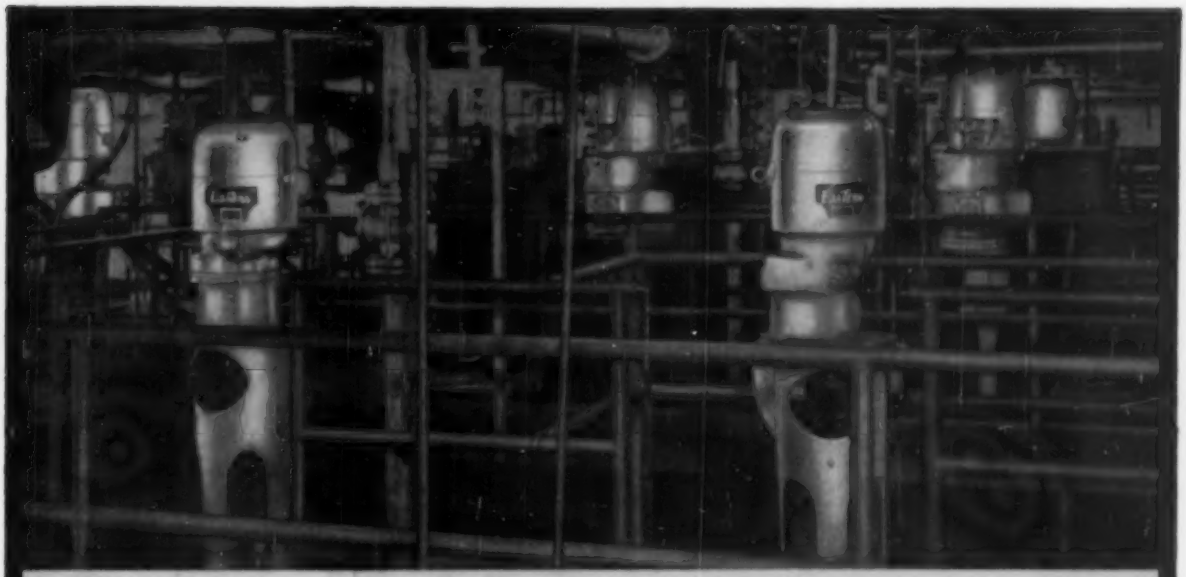
Once again, Executive Secretary F. J. Van Antwerpen will preside over a meeting of committee chairmen and vice-chairmen to bring into closer coordination the activities and directions of the various committees of the Institute.

Not All Work

If you can find time to come up for air (as the Ichthyologists would put it) from the "swim" of Technical Program events, committee meetings, special features, speeches and lectures, you'll probably realize you *are* in Boston—a center of entertainment, good food, and culture. Take your pick: historical sites, hockey games, concerts, Broadway shows "trying-out" (you may, without any difficulty, be able to see a show which would cost you perhaps $75 after it becomes a hit—if you could get tickets at all), centers of research and engineering education to visit, perhaps a rental-car drive through the countryside of the "cradle of American liberty," and all the good food you can eat—don't forget those baked beans and the chowder made (New England style) with *milk!*

CORRECTION

On page 53 of the October issue of *CEP*, E. G. Holzmann was incorrectly listed as the Shell Development representative on the Round Table on Automatic Control of Chemical Process Plants. The correct representative will be Sherman F. Duschkes.



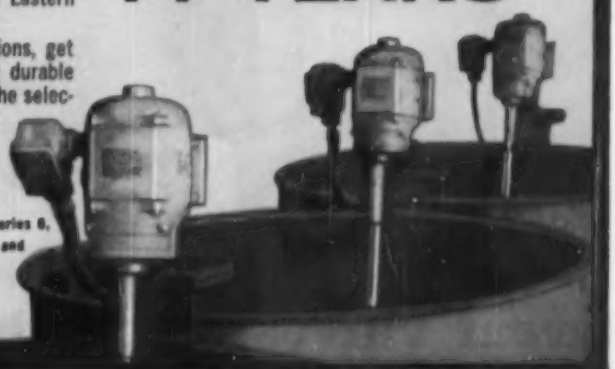
Back in 1942 the new synthetic rubber program was of urgent importance to the war effort. Naugatuck Chemical Company, Division of U.S. Rubber Co., developed processes that included fluid mixing applications. Many of Naugatuck's top-entering and portable mixers were engineered and manufactured by Eastern Industries specifically for these processes.

After fourteen years of hard, continuous service, these Eastern Mixers continue proving their built-in **reliability.**

If you have a process entailing critical operating conditions, get a long-term guarantee on your investment by selecting durable Eastern Mixers. Eastern offers engineering assistance in the selection of proper mixers from the complete Eastern line.

CONTINUOUS SERVICE . . .

14 YEARS



Eastern
INDUSTRIES, INC.
Mixer Division
Regent Street
Norwalk, Conn.

Write for Catalog Series 6, containing product and engineering data.

PORTABLE MIXERS

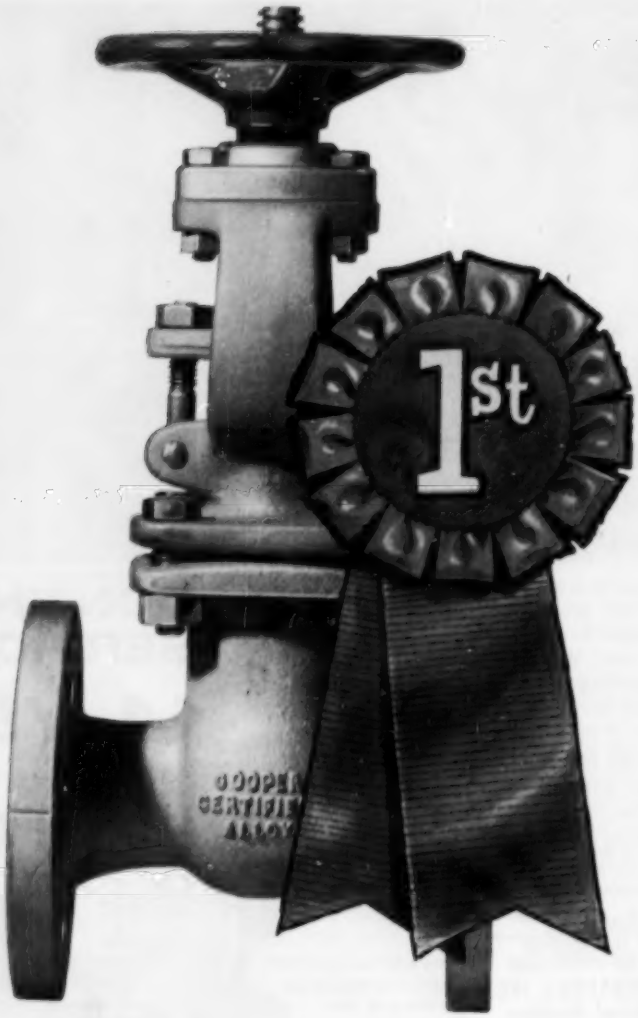
Various models offer a choice of speeds and H.P. dependent upon the consistencies of fluids. All models are available with shafts and propellers of various alloys. Single and dual propellers, and a wide choice of motors give flexibility to handle the most critical of operating conditions.

TOP & SIDE ENTERING MIXERS

Heavy-duty models cover the range from ¼ to 30 H.P., at speeds from 280 to 1725 R.P.M. Versatile in design . . . rugged in performance, these mixers offer a wide choice in mounting arrangements and motors. All side entering models are available with stuffing boxes which can be repacked with a full tank.

TURBINE MIXERS

Many of the Eastern Turbine applications include blending, dissolving and heat transfer. A variety of motor mounts and stuffing boxes available within a H.P. range of ¼ to 40, add flexibility to the Eastern line.



Great valves aren't born–they're made!

We don't mean to take any of the credit from the creative minds of our engineers whose thoughts travel beyond the desk top . . . but we've lived with valve design long enough to know that those superior design features of the COOPER ALLOY valve reflect a down-to-earth know-how that stems from first hand experience with field problems.

COOPER ALLOY engineers keep their feet on the ground by holding valve clinics on the spot in those companies who are plagued with problems of contamination, corrosion, or excessive maintenance. They have built their knowledge by means of intimate contact with plant engineering people at Dow, DuPont, Pfizer, Celanese, Mathieson and many others, and in turn have passed this accumulated experience along to others. If you would like to have one of these clinics held in your plant, drop a note to our Public Relations Division. No obligation of course.

"75 Questions" a selection of the questions asked most often at our clinics is available on request.

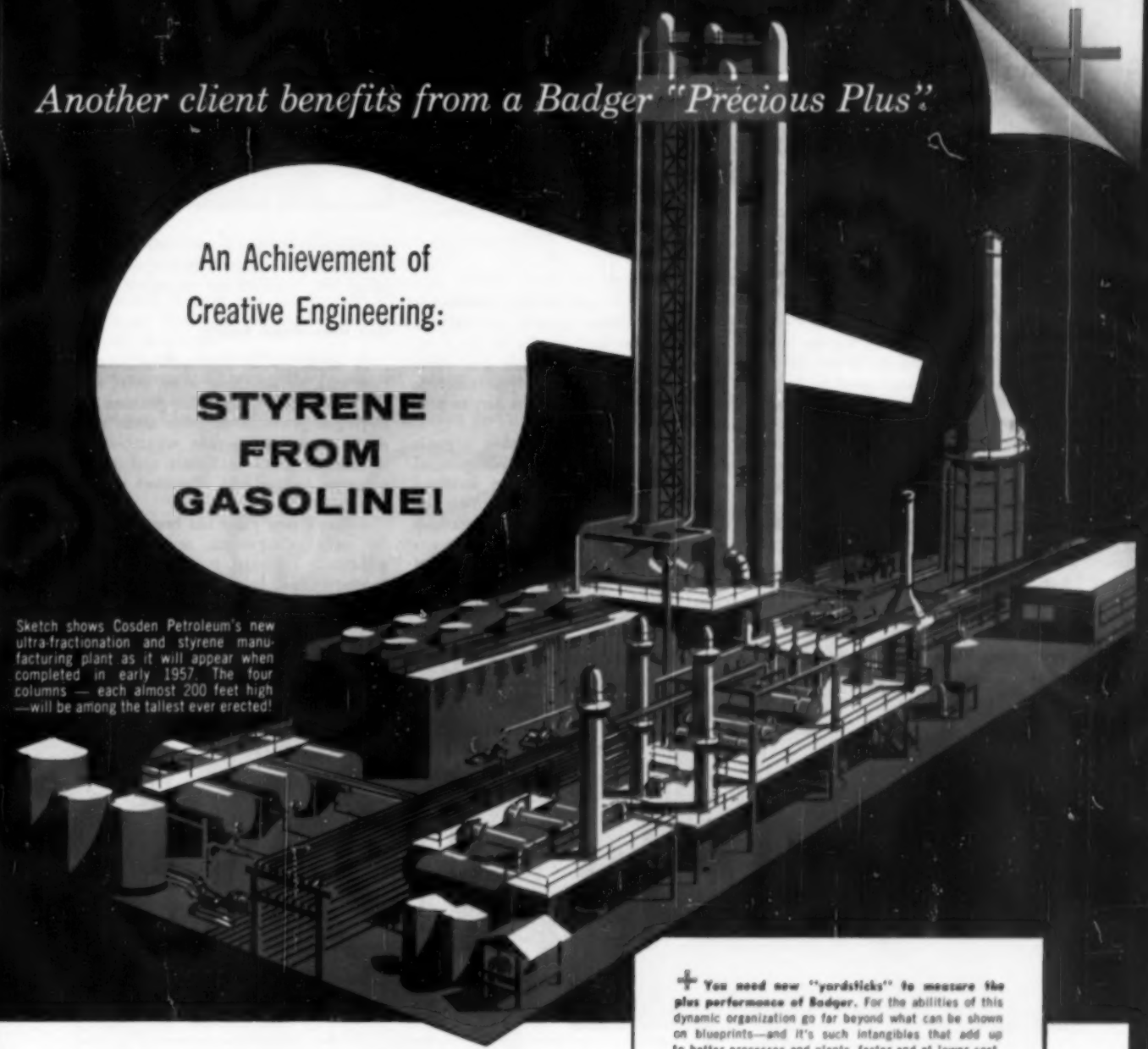
Valve & Fitting Division

COOPER ALLOY
CORPORATION • HILLSIDE, N.J.

Another client benefits from a Badger "Precious Plus"

An Achievement of Creative Engineering:

STYRENE FROM GASOLINE!



Sketch shows Cosden Petroleum's new ultra-fractionation and styrene manufacturing plant as it will appear when completed in early 1957. The four columns — each almost 200 feet high —will be among the tallest ever erected!

The plant that "couldn't be built" now under construction

At Cosden's Big Spring, Texas, refinery, Badger is erecting the first plant ever designed for the recovery of ethyl benzene by distillation. The process *first* became commercially practical when Badger Engineers developed Ultra-fractionation.

Now, instead of marketing catalytic reformer effluents as mixed solvents, this new distillation process will make it possible for the client to produce a pure product with a far higher profit margin.

This achievement in *Creative Engineering**, like all intangibles, can never be shown on the blueprints. Yet it is the "Precious Plus" in Badger's performance that is making Cosden's plant possible!

Other leading companies, too, find Badger's *plus* in performance of precious advantage — whether their need is design, engineering or construction. How else explain the unusual growth Badger is enjoying?

You need new "yardsticks" to measure the plus performance of Badger. For the abilities of this dynamic organization go far beyond what can be shown on blueprints—and it's such intangibles that add up to better processes and plants, faster and at lower cost.

***Creative engineering . . .** whether your process problem is common or complex, Badger engineers solve it with fresh thinking that frequently produces new efficiencies, unexpected savings.

Broad experience . . . Badger Engineers are more than competent—most staff members are recognized authorities in their fields.

Key Man operation . . . the Badger man who submits your proposal is always a principal—always the Key Man responsible for the execution of your job. Clients say, "This is the Badger difference that makes the difference."

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TURN FOR MORE NEWS ON
INDUSTRY .....page 56 et seq.
OVERSEAS .....page 100
NUCLEAR .....page 112
INSTITUTIONAL .....page 120

NEW HYDROGEN PEROXIDE PLANT USES NOVEL CHEMICAL PROCESS

The new hydrogen peroxide plant of Solvay Process Division, Allied Chemical & Dye Corp., at Syracuse introduces a new chemical process for the production of this important chemical.

Produced commercially in Europe since 1873, hydrogen peroxide is one of the most versatile chemicals used by industry, consumption has steadily increased to some 40 million pounds in 1955, new applications are continually being found.

Initially produced by the barium process, about 1910 the electrolytic methods were introduced in Europe. Now a chemical process is being introduced. The new process was initiated by Allied Chemical's Central Research Laboratory at Morristown, N. J., and perfected in pilot plant work by a team of engineers and chemists at Solvay's Syracuse Research Center.

The Process

Basically, the new process involves a chemical oxidation reaction, a catalytic hydrogenation, and results in the combining of by-product hydrogen from Solvay's adjacent electrolytic chlorine cells, with oxygen from the air, to produce hydrogen peroxide.

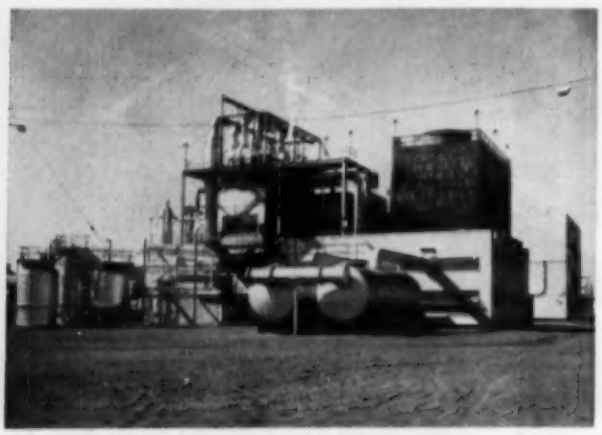
Oxygen-containing complex organic materials are catalytically hydrogenated with the by-product hydrogen, oxidized into a working solution containing hydrogen peroxide, and the hydrogen peroxide is then washed out in an extractor using a countercurrent flow of water. The original organic solution is then re-cycled and used again. After extraction, the dilute peroxide flows to a concentrator where it is evaporated to 35 or 50% strength for shipment.

New Uses—Stable Supply

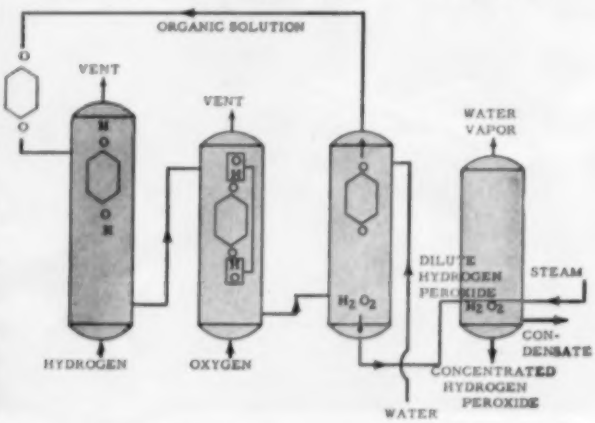
In addition to the well-established uses such as bleaching wood pulp, textiles, etc., the future holds promise for hydrogen peroxide in other areas such as its ability to upgrade vegetable oils to valuable plastic materials, and its importance in the field of rocket propellants.

Solvay's new plant has been designed for easy enlargement, and this, plus additional capacity installed by other producers, will help ensure a stable supply situation for future developments.

View of Solvay's new-process hydrogen peroxide plant at Syracuse, N. Y.



Flow diagram of the new process, with the chemistry superimposed.



An $11 million plant for the manufacture of methyl methacrylate will be built by Hercules Powder Co. and Imperial Chemical Industries, Ltd., of England, on a 20-acre site at Louisiana, Mo. The plant, with an annual capacity of 35 million pounds, will adjoin Hercules' Missouri Ammonia Works. A new company will be formed to build and operate the plant, with Hercules and ICI each owning 50%. ICI, pioneer of the process used throughout the world for the synthesis of methyl methacrylate monomer, will bring its long experience in the production and research connected with the product, and Hercules will bring a technical organization experienced in U. S. production methods, an established position in U. S. markets, and the site where basic raw materials are available. □

Furfural and charcoal briquettes will be produced in the new $3 million plant of the Cumberland Corp., Lexington, Ky., under construction at Burnside, Ky. High temperature vertical retorts will carbonize hardwood chips after prior take-off of furfural. The company has patent rights on a process for extracting furfural from hardwood waste, and further research to refine production techniques is now being carried on. Initial production will be all charcoal, furfural is expected to follow within a year. □

New construction to substantially expand production at Foote Mineral Co.'s Electromanganese Division in Knoxville, Tenn., is underway, will cost $2 million, is expected to be completed in early 1958. □

A gasoline extraction plant will be designed, engineered and constructed by the Fluor Corp. for Union Oil & Gas Corp. of Louisiana, and Texas Gas Exploration Co., at Eunice, La. The plant will process 300 million standard cubic feet per day of natural gas for extracting natural gasoline, commercial butane and propane, will be completed about June, 1957. □

The small solid-propellant rockets that will be used as power units to spin-stabilize the third stage of the Earth satellite launching vehicle and to separate the burnt out second stage rocket shell from the third stage satellite assembly, will be provided by Atlantic Research Corp. of Alexandria, Va., under subcontract from the Martin Co., Baltimore. □

S/K apades in industry

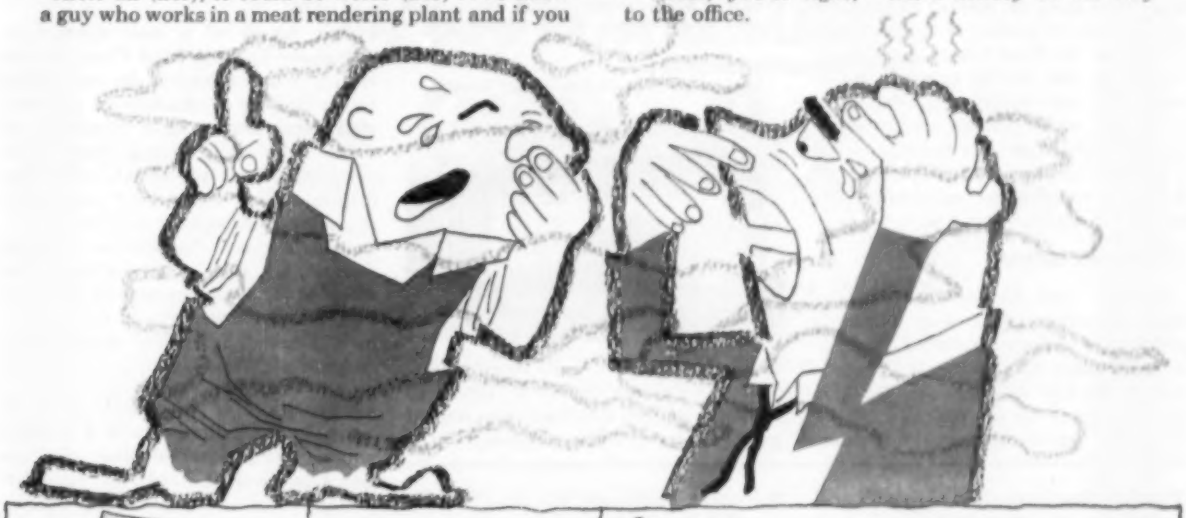
HOW TWO ENGINEERS BEAT THE HEAT AND SOLVED AN ODOROUS PROBLEM

The locale—the plant of a manufacturer of soap and allied products. The pressing problem—a 110° F temperature combined with ammonia fumes, produced during the making of Theobromine, which made working conditions unbearable in a section of the plant.

"Let's (kof-kof) look at the bright side, boss," suggested Shorty, the assistant plant engineer. "After all (kof), it could be worse (kof) . . . I know a guy who works in a meat rendering plant and if you think this situation smells, you—"

"SMELLS—SCHMELLS," screeched Barney, plant engineer and boss. "I KNOW (squrk) WHAT I THINK (hack). I THINK IF THIS SITUATION ISN'T SOLVED SOON, YOU'LL—*rendering plant?* You said rendering plant. SAY, didn't I see something about how an SK Fume Scrubber solved a fume problem in a rendering—"

"Boss, you're right," called Shorty on his way to the office.



"HERE IT IS!" shouted Shorty, reading, "SK FUME SCRUBBER ELIMINATES OBNOXIOUS FUME PROBLEM. Say, let's get an SK engineer in here."

And, they did. In no time at all, an SK Sales Engineer arrived, made an on-the-spot survey of the situation, and recommended the immediate installation of an SK 36" Fume Scrubber.

AND A BONUS—Now, air cooling and fume removal are both accomplished by the Fume Scrubber. Hot air and fumes pass through the scrubber where the ammonia fumes are removed and the hot air cooled. The air then passes through a scrubber box (equipped with SK Spray Nozzles), is further cooled, passes through heaters which raise its temperature to 70° F and reduce humidity to 70%, and returns clean and cool, to the building. The only operating cost is that for power to pump the pressure water which comes from a nearby quarry and well.

MORAL: *Chemical processing, food, or petroleum refining—no matter what business you're in—get acquainted with SK Fume Scrubbers. Send for Bulletin 4-R. Make use of a jet apparatus specialist, your nearest SK Sales Engineer.*

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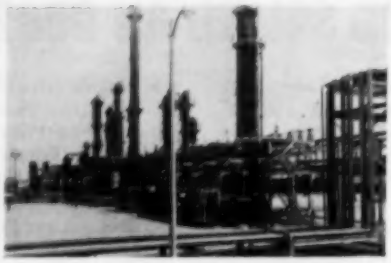
JET APPARATUS: Ask for Condensed Bulletin 3-T.
ROTAMETERS & FLOW INDICATORS: Ask for Condensed Bulletin 10-RA.
VALVES: Ask for Condensed Bulletin V-1.
HEAT TRANSFER APPARATUS: Ask for Condensed Bulletin HT-1.
GEAR PUMPS: Ask for Bulletin 17-A.

NEW CARBIDE PLANT FIRST ON WEST COAST

The Pacific Coast's first petrochemical plant producing ethylene oxide, ethylene glycol, and polyethylene is the now-in-full-operation Torrance plant of Carbide and Carbon Chemicals.

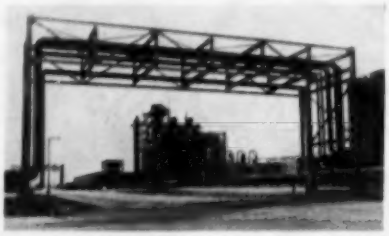
The choice of Southern California for the site of the Union Carbide and Carbon Division's new ethylene chemicals plant was dictated both by availability of raw materials and an expanding market. Until now, the market for ethylene glycol, a major product of the plant, was limited on the West Coast. Now, based largely on the rapidly growing use of automobile air-conditioning, the glycol is finding an important market in an area of high automobile density.

Production processes at Torrance are largely controlled by automation and are on-stream 24 hours a day.



Petroleum gas separation unit at the Torrance plant where ethylene is the principal gas.

Ethylene glycol production unit at Torrance.



Air-Pollution Control

Carbide and Carbon has invested some $2 million more than is usually required in equipment to avoid air pollution. Because the problem is so important in the Los Angeles area, the company designed for air pollution control from the beginning, using the recommendations of the Los Angeles Air Pollution Control District in regard to installing devices that dispose of unused gases without polluting the air.

The fact that in the last ten years concentration of value in process units has risen so greatly (single unit investments on the order of $10 million are relatively common), has made it necessary to have more effective efforts by industry to safeguard petroleum and chemical properties against fire, explosion and other such accidents.

George Armistead, Jr., internationally known consultant on industrial safety and fire protection, pointed out the need for full recognition of protection requirements by management, engineering, operations, and the rank and file of employees. He strongly recommended the study of actual loss causes as a means of protection. □

Filtration Engineers, Inc., has become a subsidiary of American Machine and Metals, Inc. Filtration is a manufacturer of continuous rotary vacuum filters. □

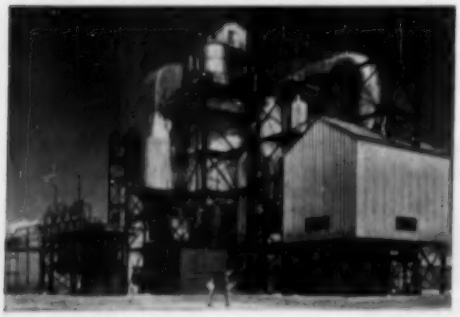
A new plant to produce vitamin B-12 from the dried and sterile sludge of the Milwaukee Municipal Sewage Disposal Plant is already under construction in Milwaukee. The material, known as Milorganite, will be processed by a new company formed in an agreement between the Milwaukee Sewerage Commission and the Vern E. Alden Co., Engineers, of Chicago. Entire output will go to The Armour Laboratories, a division of Armour and Co. □

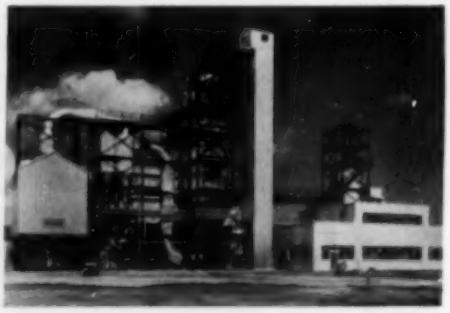
A contract for the design and construction of a 300-ton/day ammonia synthesis plant for Petroleum Chemicals, Inc., has been awarded to Foster Wheeler Corp., New York. Located at Lake Charles, La., the $12 million plant is expected to be completed in the fall of 1957, will use the Casale ammonia synthesis process. Nitrogen will be supplied by an air separation plant, hydrogen by low-temperature fractional condensation of three hydrogen-rich streams from nearby Conoco and Cities Service refineries. □

Under terms of a new agreement, Allegheny Ludlum Steel Corp. is selling its technical knowledge and patent rights for the production of consumable electrode vacuum remelting of steel and ferrous group base alloys to the Midvale-Heppenstall Co. of Philadelphia. High temperature superalloys produced by Allegheny Ludlum in consumable electrode furnaces are in great demand for use in jet engines. The entry of Midvale-Heppenstall into the field will aid materially in meeting the high demand for these high purity alloys. □

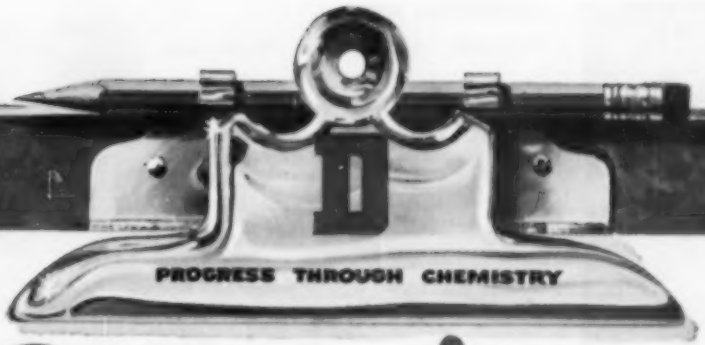
Construction is scheduled to begin early in 1957 on the new 3 million pound/year resorcinol plant of Heyden Chemical at Fords, N. J. Engineering is already underway, completion is planned for December, 1957. The process used will be a new and improved one developed by Heyden. □

Pilot plant production of a new delayed action accelerator is now underway at American Cyanamid's Rubber Chemicals Dept. Called Dibs accelerator, the new product is specially designed for tire manufacturers and others who encounter severe scorching problems in processing. Chemically the accelerator is N,N-diisopropyl benzothiazole-2-sulfenamide. Its melting range is 131 to 139° F. It has good storage stability under normal temperature conditions. □





Marking the first application of spray drying to the instant starch field, these two views of the new spray-drying chamber and plant of Corn Products Sales Co. in Corpus Christi, Tex., prominently display the 88 foot spray-drying chamber. This chamber and most other equipment is fabricated completely of stainless steel to safeguard the purity of the starch. The most modern food engineering techniques have been built into the plant by its designer and builder, the Chemical Plants Division of Blaw-Knox.



Davison...leader in Silica Gel

Davison pioneered in the development of the first commercially useful silica gel more than three decades ago, and for years has been America's leading producer. Silica gel, with its porous amorphous physical structure providing a surface area of 90,000 square feet per cubic inch, is a unique compound of continuing importance and increasing application. Silica gel's most important properties are its ability to condense and retain condensable gases in the porous structure and its regenerable nature through the application of heat or other elutriation methods. A wide variety of particle sizes, densities and adsorptive capacities are available, each having been developed to meet specific application demands. Investigate Davison Silica Gel, now.
See your Davison Field Service Engineer or write for technical literature.

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Division of W. R. Grace & Co.

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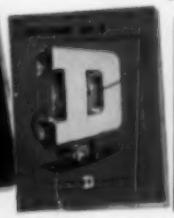
ask for . . .

Davison Silica Gel for the dehydration of air and gas.

Syloid® 308 . . . lacquer flatting agent.



Syloid® AL-1 . . . prevents gas build-up in metallic paint.

Protek-Sorb® 121 . . . for Method II dehydrated packaging.

Syloid® 162 . . . alkyd-urea varnish flatting agent.

Syloid® 244 . . . superior flatting agent in clear alkyd finishes and oleoresinous varnish.

Basic to Dependable Lab Ware -VITREOSIL

The most exacting needs of laboratories throughout the world are most eminently and successfully met by *Vitreosil* ware (pure fused silica) produced to the highest standards of quality.

Chemical purity, high resistance to heat shock, unusual electrical resistivity, best ultra-violet transmission (in transparent quality) and low initial cost compared to platinum are some features of *Vitreosil* fused quartz.

In addition to our unusually large stock of transparent and opaque, including glazed and unglazed crucibles, evaporating dishes, beakers, tubing and rods in all diameters and sizes, we offer prompt fabrication of special items.

Write today, giving full details of your requirements or ask for illustrated bulletin.

THERMAL AMERICAN FUSED QUARTZ CO., INC.
18-20 Salem Street, Dover, New Jersey

Please send illustrated bulletin or information on_____

_____

Company_____

Name_____ Title_____

Street_____

City_____ Zone____ State_____

COMPUTERS FOR COMPRESSORS

New research facility demonstrated by Worthington will cut months to days in the development of new compressors.

A closed circuit test loop with an integrated electronic digital computer, believed to be the first of its kind, was recently demonstrated by Worthington Corp. at its Harrison, N. J., research and development laboratory.

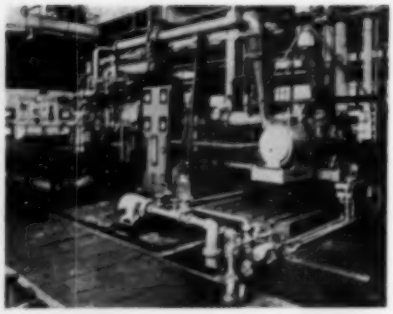
The loop will be used for the testing and developing of new products, particularly compressors for air conditioning and refrigeration equipment, and to determine performance ratings for production quality control.

Hours, Not Months

According to M. M. Lawler of Worthington, the new research tool with its electronic processing equipment "will enable us to accomplish in hours or a few days what formerly took months."

The loop has sufficient capacity to test the giant centrifugal compressors which are vital in so many industrial processes.

It is now possible to simulate exacting field conditions in the laboratory, to test new designs under these conditions, and to compute the results quickly.



Centralized control panel (left) of new test loop permits quick readings of flow, pressure, power consumption, etc., which is then fed into electronic computer equipment.

Testing Standardized

The compressor to be tested is mounted on a base and connected to a steam turbine driver. After starting, automatic control systems come into play to bring the compressor to a prescribed set of operating conditions. Flow, pressure, temperature, power consumption, etc., are measured and fed into an electronic computer which translates the figures into useful performance characteristics.

In the computer, six hundred and three programmed steps are required to evaluate completely the real fluid thermodynamic relationships of the gas and the performance of the compressor under study.

What is believed to be the largest one-piece fractionating tower ever built, a twenty-one-story giant 11 feet 8 inches in diameter and weighing 410,000 tons, is raised into place at Esso's Baton Rouge Refinery. The tower was fabricated in a single piece by Delta Tank Mfg. Co., a wholly-owned subsidiary of General Gas Corp.

An investment of some $50 million in synthetic rubber and petrochemicals will be made by Firestone Tire & Rubber. The investment will cover present and projected construction to provide more than 200,000 tons of synthetic rubber a year as well as 40,000 tons of butadiene and 75,000 tons of styrene, the principal raw materials for synthetic rubber. Construction, in the works and planned, includes a butadiene plant at Orange, Texas, which will be completed early in 1957, and a styrene plant at the same location scheduled for construction during 1957. □

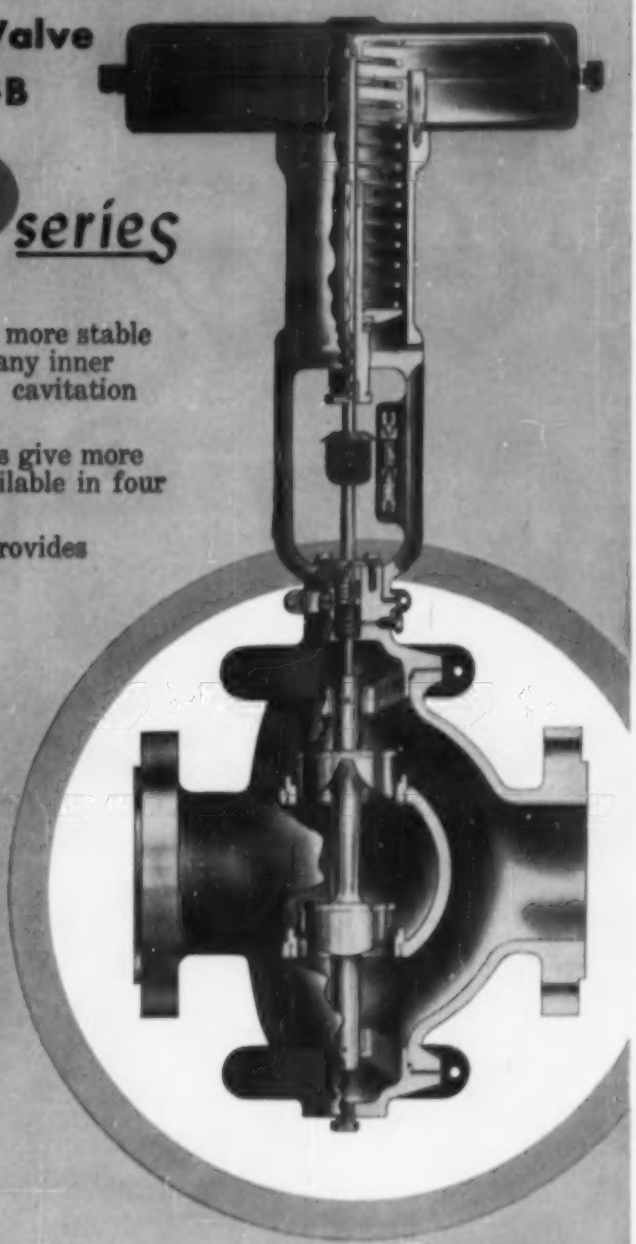
A satisfactory two-year contract settlement has been made with the Steelworkers' Union by Clark Bros., Olean, N. Y. Clark, one of the Dresser Industries, is a builder of gas engines, gas compressors, and gas turbines. □

New facilities will make possible an increase of about 20% in the output of pigment dispersions in vinyl resins and a broad line of transparents for foil and metal coatings at the Doylestown, Pa., plant of Pennsylvania Color & Chemical Co. New unit is planned to go on-stream during the first quarter of 1957. □

TAKE A GOOD LOOK...

...At The Redesigned Valve Body Of The New BS&B

Super 70 series



NEW — Streamlined flow contours provide more stable flow at all rated differentials and any inner valve position. Turbulence and cavitation are minimized.

NEW — Accurately engineered inner valves give more exacting flow characteristics. Available in four types, top and bottom guided.

NEW — Patented all-metal float ring seal provides positive self-actuating closure... tightens with the application of pressure.

NEW — Forged clamp ring allows yoke orientation to any position. Requires only two bolts... eliminates annoyance of gasket replacements.

Super "70" Series valve bodies are available in three styles...single port, double port and split body for use in erosive or corrosive fluid service where easy removability of valve seat is desirable. All bodies can be reversed without change of parts or special tools. Split and bolted stem connector is strong, easily accessible and quickly assembled. Bolted stuffing box assembly with stainless steel follower includes spring-compressed Teflon as standard packing. Steel bodied valve dimensions are in accordance with ASA Standards B 16.5—1953.

BS&B — Efficiency Reliability — Another Example of Product Leadership

This advertisement highlights features of the Super "70" Series Valve Bodies only. Another will detail features of the Super "70" Series Topworks. Watch for it!

BLACK, SIVALLS & BRYSON, INC.

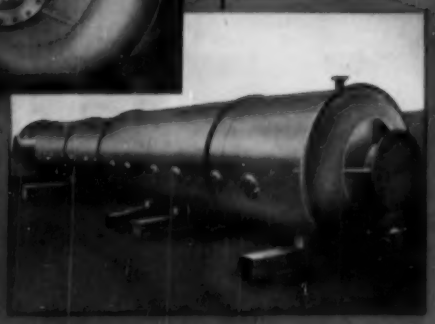
Controls Division, Dept. 4-DX11

7500 East 12th Street — Kansas City 26, Missouri

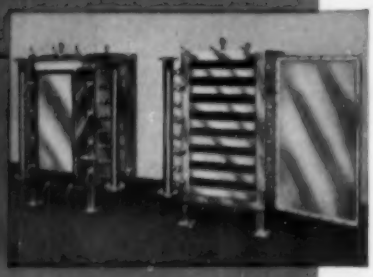
VERSATILITY

* DESIGN
* ENGINEERING
* FABRICATION

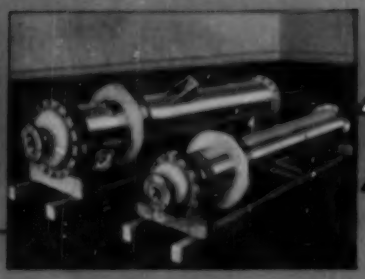
STEEL
Distilling Column



STAINLESS STEEL
Tray Dryers, ACME Design



COPPER
Scotch Whiskey Stills, 13' 7" and 12' 6" Diameters



ALUMINUM
Heat Exchangers

Leading Process Industries have come to depend on Acme for more efficient equipment for virtually any purpose. Acme versatility has paid dividends to many processors in time and effort saved, in greater economy of operation and more productive yields of high quality products.

The illustrations shown here are but a few from thousands of diverse units in current, successful use all over the world.

When planning a replacement or expansion program, consult Acme first!

ACME
Processing Equipment
ACME COPPERSMITHING & MACHINE CO., OBELAND, PA.
DESIGN AND FABRICATION IN ALL FERROUS AND NON-FERROUS METALS

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100	101	102	103	104	105	106	107	108	109	110	111	112	114

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IFC 3R 4A 6L 7A 8L 9A 10L 11A 12A 14L
15A 16A 17A 18A 20A 22L 23A 24L 25A 26A 27A
28A 29A 30L 31A 32A 33A 34L 35A 36L 37A 38A
39A 40L 41A 42A 44A 440A 45A 48A 49A 51A 52A
53A 55A 57A 58L 59A 60A 65A 67A 69A 71A 73A
74L 75A 76L 77A 78L 79A 80L 81A 83A 84L 85A
86L 87A 88L 89A 90L 91A 92L 93A 94L 95A 96L
97A 98L 99A 100L 101A 102L 103A 104BL 104BR 105R 107A
108L 109A 110L 111R 112L 112R 113R 114TL 114BL 115R
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133R 134TL 134BL 135TR 135BR 136L 137TL 137BL 137TR 137BR
138TL 138BL 139TL 139BL 139R 149TR 149BR 150L 151BL 151R
IBC OBC

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State.....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

November, 1956

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53A 55A 57A 58L 59A 60A 65A 67A 69A 71A 73A
74L 75A 76L 77A 78L 79A 80L 81A 83A 84L 85A
86L 87A 88L 89A 90L 91A 92L 93A 94L 95A 96L
97A 98L 99A 100L 101A 102L 103A 104BL 104BR 105R 107A
108L 109A 110L 111R 112L 112R 113R 114TL 114BL 115R
116L 117R 120L 121R 122TL 122BL 123L 123R 124L 124R
125R 127R 129A 130L 131TL 131BL 131TR 131BR 132B 133L
133R 134TL 134BL 135TR 135BR 136L 137TL 137BL 137TR 137BR
138TL 138BL 139TL 139BL 139R 149TR 149BR 150L 151BL 151R
IBC OBC

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

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☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

November, 1956

the chemical engineers'

DATA SERVICE

and

GUIDE

to significant developments in

- **EQUIPMENT**
- **MATERIALS**
- **SERVICES**

developments of the month–

100 Analog Computing Guide. Electronic Associates, Inc. offer reprint of article "A Practical Approach to Analog Computers." This introduction to simulation technique presents the basic elements of an analog computer in terms understandable to the average chemical engineer.

Operation of computer components such as attenuators & operational amplifiers is explained in detail. Sample circuits & hookups for solving various types of problems are shown with special reference to the Electronic Associates' Model 16-31R, a typical general purpose analog computer (see photo above).

(Continued on page 62)

TURN THIS PAGE TO RIGHT FOR MORE

HOW TO USE THIS POST CARD FOLDER

Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

products-

advertised in this issue

IFC Acrolein Derivatives. Pentanediol-1,5, glutaraldehyde, 2-chlorallylidene diacetate available in tank cars and drums. Carbide and Carbon Chemicals Co. Samples and information.

3R Rotary Sifter. Bar-Nun Sifter for dry chemicals saves floor space. B. F. Gump Co. Details and recommendations.

4A Demisters. Yorkmesh Demisters improve performance of concentrators, evaporators, vacuum pans. Otto H. York Co.

6L Laboratory Glassware Catalog. Custom-engineered glassware assemblies and components for reduced-scale work. Ace Glass, Inc.

7A Vinyl Resins. Exon resins, made by Firestone Plastics Co., have outstanding anti-corrosion characteristics.

8L Hydrocarbon Resins. Panarez resins improve quality of shoe soles, floor tile, wire covering, tires. Pan American Chemicals Corp.

9A Flow Control Systems. High standards of accuracy and reliability are assured by use of Pottermeters. Potter Aeronautical Co.

10L Teflon Packing. Packing for every process need. U. S. Gasket-Belmont packing. Catalog.

11A Process Filters. Elmco filter stations save time, money and effort. Literature. The Elmco Corp.

12A-13A Temperature Control Instruments. Complete line of temperature indicators, recorders and controllers. Literature. Foxboro Co.

14L High Vacuum Equipment. Absolute pressures in the range of 1 to 100 microns. Graham Manufacturing Co.

15A Electronic Computer. M. W. Kellogg Co. has installed a new, large magnetic drum digital computer for process calculations.

16A Asbestos Insulation. Johns-Manville Thermobestos adds high strength and light weight to low thermal conductivity. Literature.

17A Water Filtration Equipment. R. P. Adams Co. offers filtration equipment to meet every water treatment need. Consulting Services.

18A-19A The new Parma, Ohio, laboratories of National Carbon Co. are doing important fundamental research in carbon physics. Booklet "Research" offered.

20A-21A Conveying Systems. Speed, safety, and economy are features of chemical product conveying systems built by Stephens-Adamson Mfg. Co. Bulletin.

22L Spiral-ribbon Mixers. Read Standard Corp. counterflow action spiral ribbon mixers are ideal for granular or pulverized, wet or dry materials. Literature.

23A Diaphragm Control Valve Catalog. The K & M fully molded diaphragm gives constant effective diaphragm area. Kieley & Mueller, Inc.

24L Vaporizers. Specialized engineering services for vaporization problems. Richard M. Armstrong Co. Inquiries invited.

25A Activated Carbon. Increased efficiency, reduced costs, higher product quality. Pittsburgh Coke & Chemical Co.

26A Gyratory Screen. Stacked-deck design of Allis-Chalmers stainless steel gyratory screen provides up to 35 sq.ft. screening area in 16 ft. of floor space.

27A Chemical Porcelain. Tufclad chemical porcelain, product of Lapp Insulator Co., is armored with fiberglass-reinforced plastic for added protection. Specifications sent.

28A Process Filters. All types of filters for the chemical industry are offered by Sparkler Manufacturing Co.

29A Sulfur. Freeport Sulphur Company's development program assures uninterrupted flow of sulfur in large quantities.

30L Vertical Pumps. Open or enclosed Verti-Line pumps give low first cost, economical operation, and negligible maintenance. Layne & Bowler Pump Co. Bulletin.

31A Carbon and Graphite Products. High-grade graphite electrodes, anodes, molds and specialties. Great Lakes Carbon Corp.

32A Process Equipment. Glassed steel and alloy process equipment of all types for the chemical processing industry. The Pfaudler Co. Data sheet available.

33A Engineers Wanted. The Chemstrand Corp. has openings for chemical, mechanical, industrial, textile and instrument engineers. Detailed information sent.

34L Oil Reclaimer Systems. The Hilco Oil Reclaimer offers continuous, all electric, automatic operation, low operating temperature. Hilliard Corp. Bulletin.

35A Molecular Sieve Adsorbents. Linde molecular sieves, a new class of adsorbents, offer unique performance in product purification and recovery. Linde Air Products Co. Descriptive booklet.

36L High-temperature Filters. Poro-Klean porous stainless steel filters provide 3-30 micron filtration in hot spots and tight places. Cuno Engineering Corp. Literature.

37A Rotary Airlock Bulletin. Mikro Rotary Airlock permits feeding free-flowing materials under pressure or vacuum while preventing passage of air or gas. Metals Disintegrating Co., Inc.

38A Lubricated Plug Valves. Quick and positive operation, one quarter turn to open or close. Wm. Powell Co. Literature.

39A Nitric Acid Plants. Nitric acid plants designed and built by the Girdler Co. offer lower capital investment and lower operating costs. Bulletin.

40L Air Classifier Systems. The Hardinge Gyrotor Classifier system, combined with a Hardinge grinding mill, is an integrated grinding, classifying, and product conveying system. Hardinge Co. Bulletin.

41A Dowtherm Heat Transfer Medium. Temperatures up to 750° F. at pressures below 150 lb./sq.in. Dow Chemical Co. Literature.

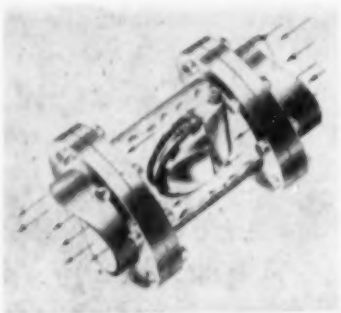
42A Noble Metal Catalysts. Houdry platinum and palladium catalysts on hard alumina base are manufactured to obtain high, uniform hardness. Houdry Process Corp. Development services available.

44A Package Process Systems. Whitlock Manufacturing Co. offers complete engineering and fabrication services for process industries.

440A Tower Packings. Intalox Saddles give higher mass transfer efficiency and lower pumping costs. U. S. Stoneware. Technical Bulletin.

DEVELOPMENTS OF THE MONTH *(Continued)*

101 Polyvinyl Chloride Check Valve. Technocheck-PVC is said to offer versatility, tight sealing, low pressure drop, & long life in the handling of corrosive gases, vapors & fluids. Can be used in all PVC systems & installed in any position for handling salt solutions, fuels & oils, acids & alkalies, food products, liquors, alcohols, etc.



Temperature & pressure limitations are the same as for PVC. Bodies are fabricated of tubing & flanges meeting ASA Standards. Internals are of PVC, with sealing members of plasticized PVC, Neoprene, or Buna N, all reinforced with nylon for high strength. Hardware is of stainless steel.

Available in standard sizes from 1" to 8"; male threaded ends in sizes from 1" to 4" or with standard flanges or socket ends. Bulletin from Techno Corp.

(Continued on page 63)

DEVELOPMENTS OF THE MONTH *(Continued)*

45A Heating Systems. Struthers Wells Corp. supplies circulating heating systems for both liquid and vapor service.

48A Air Fractionation Equipment. Plants for the production of oxygen and nitrogen from air by low-temperature processing. Air Products, Inc.

49A Centrifuges. De Laval Separator Co. makes centrifuges for all chemical processing needs.

51A Mixers. Portable mixers, top and side entering mixers, turbine mixers. Eastern Industries, Inc. Technical Bulletin.

52A Alloy Valves. Cooper Alloy Corp. will hold valve clinic in your plant at your request.

53A Engineering Services. Creative engineering is the hallmark of Badger Manufacturing Co. in design & construction of chemical processing plants.

55A Fume Scrubbers. SK fume scrubbers find application in the chemical processing, food and petroleum industries. Schutte and Koerting. Bulletin.

57A Silica Gel. Wide variety of particle sizes, densities, and absorptive capacities available from Davison Chemical Co. Technical literature.

58L Fused Silica Laboratory Ware. Vitreosil ware, product of Thermal American Fused Quartz Co. Illustrated bulletin.

59A Valves. Super "70" Series valve bodies embody many new design features. Black, Sivalls & Bryson, Inc.

60A Processing Equipment. Design and fabrication in all ferrous and non-ferrous metals. Acme Coppersmithing & Machine Co. Consulting service.

65A Spray Dryers. Bulletin describing complete line of Bowen Spray Dryers. Bowen Engineering, Inc.

67A High Temperature Work Sheet. International Nickel Co. will analyze your high-temperature strength and corrosion problems. Send for work sheet.

69A High Pressure Tubing. Controlled pressure at 100,000 lb./sq. in. Details available from Superior Tube Co.

(Continued on page 64)

102 Large Capacity Spray Nozzle. Spraying Systems announces a new, large capacity flat spray nozzle. Capacity ranges from 73 gal./min. at 15 lb./sq.in. to 330 gal./min. at 300 lb./sq.in.

Supplied in choice of two types of spray angle. Nozzle is designed to be free of cores, vanes or obstructions of any kind & is made with a 2" male pipe connection. Designed for heavy duty cooling & washing operations, the 2-U-Veejet is suitable for any application where a large capacity flat spray is desired. Made standard in brass & can be supplied in other materials upon order. Literature.

(Cont. on page 64)

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

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CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

No Postage Stamp Necessary If Mailed in the United States

Postage Will Be Paid by Addressee

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CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

No Postage Stamp Necessary If Mailed in the United States

products-

advertised in this issue *(Cont.)*

71A Insulation Guidebook. Unibestos catalog helps select economic thickness of pipe insulation accurately. Union Asbestos & Rubber Co.

73A Drying Equipment. Proctor & Schwartz, Inc. specializes in the engineering of drying equipment for the chemical process industries.

74L Oil & Water Coolers. Paracoil oil and water coolers, made by Davis Engineering Corp., offer many process advantages.

75A Air Vortex Classifier. Bulletin from Sharples Corp. describes new super classifier for dry powders.

76L Filter Press Guide. T. Shriver & Co. offers guide to aid in selection of right filter press for your process.

77A Autoclave Valves and Fittings. Bulletin from Autoclave Engineers describes complete line of Speedvalves and fittings.

78L Corrosion Protection Bulletin. Atlas Mineral Products Co. will send 18-page bulletin on protective coatings and linings, etc. Technical data and charts.

79A Stainless Steel Fabrication. Sun Shipbuilding & Dry Dock Co. offers consulting services on alloy fabrication problems.

80L Free Grinding Test. Schutz-O'Neill Co. will grind a sample of your material without obligation and submit recommendations for pulverizing equipment.

81A Stainless Steel Equipment. G. O. Carlson, Inc. specializes in the fabrication of stainless steel equipment to exacting specifications.

83A Packaged Fluid Mixers. Bulletin from Philadelphia Gear Works describes technical details of line of packaged fluid mixers.

84L Graphite Heat Exchangers. Catalog from Falls Industries gives details on Impervite cross bore heat exchangers.

85A Canned Pumps. The Chempump combines pump and motor in a single hermetic unit. No shaft sealing device required. Literature from Chempump Corp.

86L Process Equipment. Bulletin from Downingtown Iron Works describes steel and alloy plate fabrication.

87A Ion Exchange Systems. Complete systems for water conditioning, chemical processing, industrial waste treatment. The Permutit Co. Literature.

88L Metallic Filter Cloth Catalog. Newark metallic filter cloth is available in all malleable metals. Newark Wire Cloth Co.

89A Plant Location Opportunities. The Norfolk and Western Railway will advise on chemical plant location.

90L Handbook on Mulling. The 3F Simpson Mix-Muller is available in 13 models. Batch capacities from 1/10 to 60 cu. ft. National Engineering Co.

91A "Hot" Shipment Containers. National Lead Co. produces containers in four sizes for shipping and handling radioactive materials.

92L Slime Control Systems. Bulletin from Wallace & Tiernan describes chlorination systems for slime control in power generating plants.

93A Pump Data Sheet. Aldrich Pump Co. also offers condensed catalog showing complete line of Aldrich pumps.

94L Mixing and Grinding Equipment. Charles Ross & Son Co. offers technical information on mixers and grinders for chemical processing.

95A Lithium Catalysts. Lithium Corp. of America invites inquiry on the possibilities of lithium compounds as polymerization catalysts.

96L Stainless Steel Heat Exchangers. Doyle & Roth Mfg. Co. makes standardized stainless steel heat exchangers to insure lower prices and fast delivery.

97A Diaphragm Valves. Crane Co. will send facts on complete line of Crane valves and fittings.

98L Cooling and Drying Towers. Maurice A. Knight will evaluate your problem without obligation.

99A Illustrated Instrument Catalog. Fischer & Porter offers complete, detailed report on the multiple applications of F&P Ratographic instruments.

100L Evaporators. Free consultation services on evaporator problems available from Goslin-Birmingham Manufacturing Co.

101A Synthetic Calcium Silicates. Micro-Cel, product of Johns-Manville, remains free-flowing after absorption of twice its weight in liquids. Technical data and samples.

102L Pump Data. Lawrence Pumps, Inc. offers bulletin giving summary of acid and chemical pump data.

103A Polyethylene Tower Packing. "Tellerette" packing is based on the principle of interstitial holdup. Free folder. Harshaw Chemical Co.

104BL Laboratory Glassware. Brochure from Doerr Glass Co.

104BR Ribbon-type Mixers. Details and prompt quotations available from Cincinnati Hildebrand Co.

105R Heat Transfer & Process Units. Manning & Lewis engineered and fabricated process equipment is made in all ferrous and non-ferrous metals. Manning & Lewis Engineering Co.

107A Process Equipment. Bartlett-Snow specializes in the design and construction of equipment for the pharmaceutical industry.

108L Woven Wire Screens. Bulletins from Cleveland Wire Cloth & Mfg. Co. give specifications on all types of woven wire screens.

109A Low Temperature Gas Separation. American Air Liquide invites inquiries on design and construction of facilities.

110L Telemetering Systems. Bulletin from Vapor Recovery Systems Co. gives details of "Varec" pulse code telemetering systems.

111R Tray Dryers. C. G. Sargent's Sons Corp. offer tray dryers in large range of capacities and designs.

112L Silicone Defoamer. Free sample of Antifoam B will be sent by Dow Corning Corp.

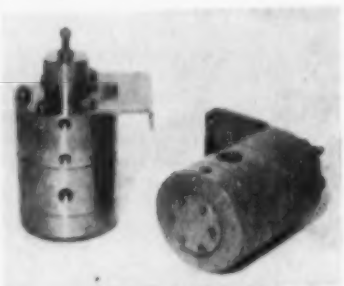
112R Flow Indicator Data Unit. Jerguson Gage & Valve Co. offers data unit covering new sight flow indicators.

113R High-alloy Castings. Bulletin from Duraloy Co. describes their production facilities.

(Continued on page 66)

DEVELOPMENTS OF THE MONTH *(Continued)*

103 Vaporizer-Regulator. New type vaporizer-regulator, made by Consolidated Electrodynamics Corp., assures vaporization & permits pressure control of liquid samples being introduced into analyzers & other petrochemical-monitoring instruments.

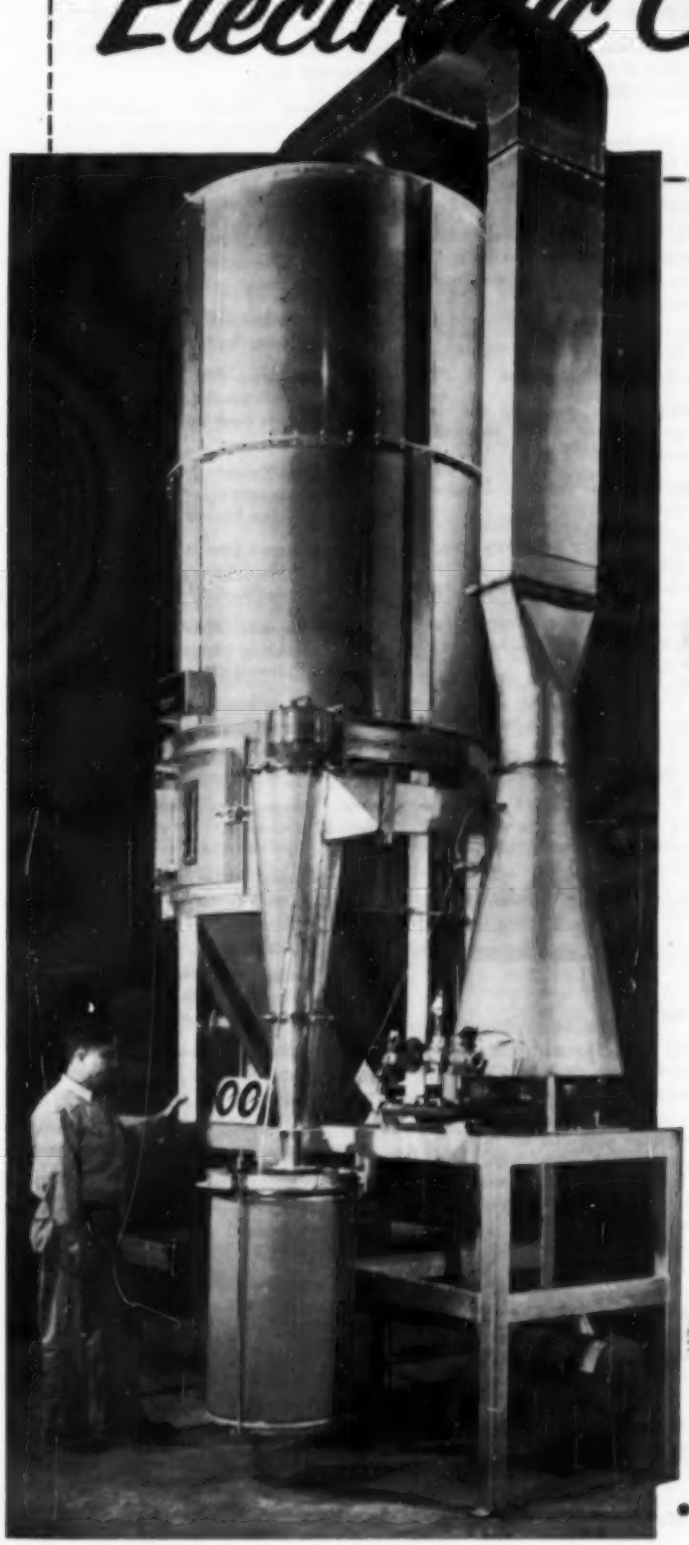


A cylinder 3⅜ in. in diam. & 6½ in. high, the unit consists of four precision-machined stainless steel segments bolted to make a cylindrical sandwich. An aluminum model is available.

The regulator is built to operate at inlet pressures of up to 150 lb./sq.in. & will hold pressure constant within 0.10 lb./sq.in. when upstream variations do not exceed 10 lb./sq.in. Outlet pressure may be regulated from 0 to 50 lb./sq.in. Maximum steam pressure is 50 lb./sq.in. and maximum heater output, when heating element is used instead of steam, is 75 watts. Bulletin.

(Continued on page 66)

Electronic Ceramics...



Uniform, spherical, free-flowing particles for pressing or extruding small electronic and dielectric parts are produced on the Bowen Spray Dryer illustrated, one of 14 already purchased by the electronic ceramic industry.

Spray drying, now a preferred process for handling ceramic slips, often eliminates many steps previously necessary such as filtering, decanting, preforming, tray drying, pulverizing, grinding, screening and classifying.

The special Bowen Ceramic Spray Dryer with its patented abrasion resistant atomizing unit embodies features to meet the specialized requirements and provide a high quality product at a low operating cost.

Your inquiries will receive a prompt reply.

Write for Bulletin #35 describing complete line of Bowen Spray Dryers.

BOWEN

BOWEN ENGINEERING, INC.
NORTH BRANCH 13, NEW JERSEY

BOWEN SPRAY DRYERS
Always Offer You More!

Recognized Leader in Spray Dryer Engineering Since 1926

● Special Bowen Ceramic Spray Dryer

products-

advertised in this issue *(Cont.)*

114TL Solvent Cement. TTP solvent cement, made by Tube Turns Plastics, is particularly suited for use with their socket type PVC fittings.

114BL Industrial Dryers. The Dehydro-Mat is designed for ammonium nitrate and other hard-to-dry chemicals. Also conventional rotary dryers. Literature from Edw. Renneburg & Sons Co.

115R Conveyor Dryer. Folder describing single and multiple apron conveyor dryers and related equipment. National Drying Machinery Co.

116L Ion Exchange Equipment. Illinois Water Treatment Co. designs and builds complete, practical, workable systems.

117R Steam Jet Ejectors. Descriptive bulletins from the Elliot Co.

120L Plastic Pipe, Fittings and Valves. Catalog from Vanton Pump & Equipment Co. Available in PVC, styrene copolymer and Buna N.

121R Flexible Ball Joints. Barco flexible ball joints are replacing hose in many hazardous applications. Barco Mfg. Co.

122TL High-purity Fused Quartz. Catalog and technical data available from Amersil Co.

122BL Adjustable Sprocket Rim with Chain Guide. Catalog sheet and prices from Babbitt Steam Specialty Co.

123L Explosion-proof Motors. Free descriptive booklet gives technical details. U. S. Motors.

123R Laminated Fiberglass Equipment. Tanks, ducts, etc. made of lolyte fabricated to your specifications. Literature from Ferro-Co Corp.

124L Chemical Engineering Catalog. Up-to-date facts on equipment, materials of construction, engineering services. Reinhold Publishing Corp.

124R Centrifugal Pumps. Bulletin on enclosed and open impeller types of centrifugal pumps. Frederick Pumps.

125R Cone Blenders. Plastic-lined cone blenders, product of Paul O. Abbe, prevent sticking of material and produce uniform mix. Literature.

127R Water Filtration Equipment. The Ranney method assures a pure, sanitary water supply by natural filtration. Ranney Method Water Supplies, Inc.

129A Filters. Illustrated bulletins from Process Filters, Inc. describe vertical leaf, vertical batch, horizontal leaf and horizontal batch filters.

130L Plastic Ductwork. Lower cost, longer service life than stainless steel. Free brochure from American Agile Corp.

131TL Portable Filters. For small batches where sludge or filter aid is required. Ertel Engineering Corp.

131TR Precision Bore Tubing. Detailed catalog from Wilmad Glass Co.

131BL Open Gear Spray Lubricant. Marla spray lubricant is economical and easy to use. Jobber inquiries invited. Rothlan Corp.

131BR Rotameter Bulletin. Step-by-step sizing instructions. Schutte and Koerting.

132B Large O.D. Steel Pipe. Fabricated steel pipe from 10" diameter up. Complete information without obligation. Posey Iron Works, Inc.

133L Flow Rate Regulators. Technical bulletin from W. A. Kates Co.

133R Teflon Products. Flexible thin-walled tubing, custom molded teflon. Brochures. Sparta Mfg. Co.

134TL Process Weighing Systems. Expert consulting services available from Glengarry Processes, Inc.

134BL Drying Agents. Florite has long service life, gives low dew point depression. Also other adsorbents. Floridin Co.

135TR Mechanical Seals. Dura Seals provide perfect sealing for wide range of fluids, pressures, temperatures and speeds. Durametallic Corp.

135BR Spray Nozzles. Comprehensive spray nozzle catalog from Binks Mfg. Co.

136L Wood Tanks and Equipment. Chemical Equipment Bulletin offered by Wendnagel & Co.

137TL Bin Level Indicator. Complete illustrated literature available from the Bin-Dicator Co.

137TR Spray Nozzles. 48-page spray nozzles catalog from Spraying Systems Co.

137BL Penetrating Oil. Marla Aero Spray penetrating oil assures penetration, with pressure, to the most hard-to-get-at objects. Rothlan Corp.

137BR Low Volume Rotary Pump. The ECO All-Chem rotary pump is described in bulletin from Eco Engineering Co.

138TL Vacuum Glassware. Bulletin on vacuum gauges, diffusion pumps and other vacuum glassware. Kontes Glass Co.

138BL Laboratory Planning Guide. 180 pages of ideas, layouts, specifications. Metalab Equipment Co.

139TL Surface Pyrometer. Free catalog on Pyro optical, micro-optical, indicating, radiation and immersion pyrometers. Pyrometer Instrument Co.

139BL Vacuum Equipment. Steam jet ejectors, condensers, vacuum equipment of all types. Jet-Vac Corp.

139R Portable Mixer Catalog. Models from 1/20 to 7½ hp in wide choice of motors and materials. Alsop Engineering Corp.

149TR Design and Fabrication Services. Processing equipment designed, developed, manufactured. Artisan Metal Products, Inc.

149BR Nuclear Engineering Services. Reactor physics, shielding, radiation chemistry, business opportunities. Astra.

150L Hand Pyrometer. Detailed descriptive literature on hand pyrometers. Claud S. Gordon Co.

151R Vacuum Equipment. Consulting services on all types of vacuum equipment. Croll-Reynolds Co.

151BL Engineering Services. Engineers and contractors for the petroleum and chemical industries. C. W. Nofsinger Co.

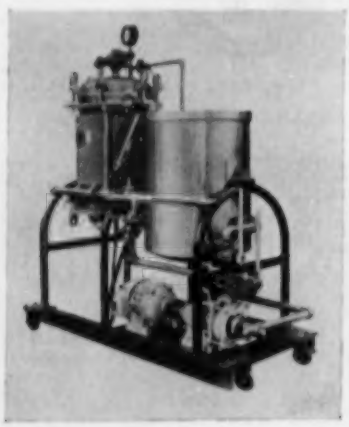
IBC Controlled Volume Pumps. Capacities from 3 milliliters per hour to 45 gal./min. Bulletins from Milton Roy.

OBC Mixing Data. Bulletins from Mixing Equipment Co. including data sheet for figuring mixer requirements.

(Continued on page 68)

DEVELOPMENTS OF THE MONTH *(Continued)*

104 Portable Filtration Station. The Durco Co. has introduced a stainless steel Durco-Enzinger filtration station as a portable package unit. The station is claimed to be ideal for pilot plant or other small batch operations.



The complete unit consists of a vertical leaf pressure filter with 21.2 sq. ft. of leaf area, a precoat and slurry tank, pump, valves, & complete piping, all mounted on a portable frame. It can be positioned & in operation in minutes.

Filter is an Enzinger Model DS 18/21.2 with either wet or dry cake discharge of filter cake. It incorporates a tailings leaf to filter the liquid heel completely. Filter shell is steam jacketed. Valves are Durco Type F with Teflon sleeves. Pump is a Series R Durcopump. Complete unit including filter, tank, pump, valves, & piping is Type 316 or Durimet 20 stainless steel.

A similar package unit can be obtained on a loan and rental basis for filtration test purposes.

(Continued on page 68)

Inco high temperature research note:

Carburization

...and its effects on metals at high temperatures

With sufficient background of information on the strength properties and corrosion characteristics, it should be entirely possible to predict the performance of an alloy under any conditions of high temperature service.

Method of Obtaining Data

Data relating to the mechanical properties may be obtained in the laboratory by any of the conventional testing methods . . . on the other hand, the problem of high temperature corrosion resistance is often so complex that it is frequently more convenient to place test specimens in an actual service environment than to try simulating industrial conditions on a laboratory scale.

This course is being pursued by Inco's high temperature engineers working in the field and in laboratories at Bayonne, N. J. and Huntington, W. Va. Creep and rupture tests at temperatures as high as 2100°F have supplied data on the strength properties of high nickel alloys. Corrosive attack by various hot atmospheres, fused salts and molten metals is being studied principally in the field to provide the type of information that will assist industry to select more suitable, longer lasting materials for various high temperature applications.

Effects of Carburization

Carburization—as may result from contact with carbonaceous atmospheres in petro-chemical or petroleum refining operations or during the heat treatment of steel parts—is one type of high temperature reaction which, under certain conditions, can change the properties of heat resistant alloys and adversely affect their performance.

Carbon diffuses into the metal and subsequently precipitates as a carbide particle rich in chromium. Compared to the alloy matrix, the carbide phase is hard and brittle. If distributed throughout grain boundaries, the particles provide a continuous path for brittle failure. (See micrograph below.) In certain types of service, carburization of a heat-resisting alloy may not be a serious matter. But in the usual case where the metal part or structure may be called upon to exhibit some measure of ductility or be subjected to impact or to drastic temperature changes, carburization often leads to premature failure.

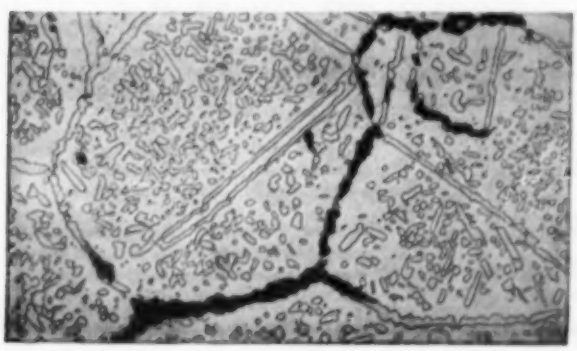
Nickel Plays Basic Role

In general terms, the susceptibility of iron-chromium-nickel alloys to carburization seems to depend upon the relative amounts of the individual components – but not as one might expect. Iron and chromium form stable carbides, while nickel does not. Yet Inco test data show that chromium has a greater effect than either iron or nickel. But it has also been demonstrated that for a given amount of chromium its beneficial effect is much greater at a higher nickel level than at a lower. Conversely, for given nickel content it would be expected that an alloy containing a higher chromium content would be more resistant to carburization.

Assistance Available

Inco high temperature corrosion test data also suggest that silicon improves carburization resistance, as does the presence of carbide stabilizing elements, such as titanium and columbium. Under extremely severe conditions of carburization, the effect of these elements is but temporary, and after sufficiently long exposure, their value is lost.

In a fast growing field such as this, it is impossible to have an immediate answer to every problem. But if high temperature performance is a problem to you, whether in present activities or in new projects, Inco High Temperature Engineers will do their best to help you. Let them send you the High Temperature Work Sheet . . . it is a big aid in getting the facts down clearly. Send for a copy now.



INCO

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

Please send me the High Temperature Work Sheet so that I may outline my problem to you.

Name_____

Title_____

Company_____

Address_____

City_____ State_____

equipment-

1 Tube Cleaners. 107-page catalog giving specifications and uses of air, water, steam & electric-driven tube cleaners. Thomas C. Wilson, Inc.

2 Pump Ailments. New booklet helps locate and correct common ailments of rotary, centrifugal and steam pumps. Worthington Corp.

3 Fine Grinders. The Attritor offers fine dispersions, fast action, low power consumption, small floor space. Union Process Co.

4 Water Filters. Automatic water filter bulletin, 10 pages, includes dimension charts and flow curves. R. P. Adams Co.

5 Nuclear Reactors. Aerojet General Nucleonics mass-produced nuclear reactors are available for purchase, lease-purchase, or rental. Complete technical data sent.

6 Vibrating Screens. Construction features of Allis-Chalmers vibrating screens described in 24-page bulletin.

7 Welding Fittings & Flanges. Full line of carbon, alloy and stainless steel fittings. Folder from Babcock and Wilcox.

8 Thermal Conductivity Analyzers. Photographs, drawings, diagrams contained in 16-page booklet. Arnold O. Beckman, Inc.

9 Submicron Filter. Particles as small as 0.45 microns can be filtered out with the MF Submicron Filter. Information available from Barnstead Still & Demineralizer Co.

10 Bin Level Indicator. New explosion-proof Roto-Bin-Dicator is approved by the Underwriters' Laboratories for a wide range of hazardous atmospheres. The Bin-Dicator Co. Illustrated catalog.

11 Rupture Discs. New type rupture disc makes possible protection of tank cars with safety heads. Literature from Black, Sivalls & Bryson, Inc.

12 High Vacuum Systems. Booklet provides guide for planning installation of high vacuum systems. Technical data, many charts. Central Scientific Co.

14 Sulfur Burning Equipment. Efficient sulfur burning equipment for sulfuric acid plants or for sulfur dioxide production. Chemical Construction Corp. Bulletin.

15 Condenser Wearing Strips. Flowrites prevent corrosion and failure of condenser tubes. Simple to install. Condenser Service & Engineering Co.

16 Instruments. 31-page bulletin from Consolidated Electrodynamics Corp. describes instruments for analysis, control and data processing.

17 Cast Steel Valves. Design, operation, construction details, accessories, material specifications, pressures, for line of cast steel valves. Bulletin from Darling Valve & Manufacturing Co.

18 Diaphragm Slurry Pumps. Two-color, 6-page bulletin from Dorr-Oliver gives features, applications, sizes and capacities of diaphragm slurry pumps.

19 Liquid Handling Equipment. Filters, portable mixers, bottle fillers, centrifugal and self-priming pumps are described in an Ertel Engineering Corp. bulletin.

20 Heat Exchangers. Impervite tube and shell heat exchangers are now furnished as standard in 14- and 16-foot lengths. Falls Industries, Inc. Literature.

21 Analog-to Digital Computer. Fischer & Porter's shaft position, analog-to-digital computer, the Digi-Coder, is now available in a new C-2-B Model. Literature.

22 Process Equipment. Tank cars, blowers, pumps, welded vessels, dryers, turbo-mixers, etc. General engineering and design services. 27-page bulletin. General American Transportation Corp.

23 Submerged Rotary Pumps. New line of submerged rotary pumps now made by Granberg Corp. Universal-joint principle, rotary positive displacement design. Literature.

24 Dry Grinding Mills. 44-page catalog from Hardinge Co. gives plant flow sheets, mill auxiliaries, grinding performance data for many materials.

25 Diaphragm Valves. Advantages, applications, specifications of Hills-McCanna diaphragm valves are included in a 12-page catalog.

26 Thermal Liquid Heaters. Process temperatures to 750° F. attainable with International-Le Mont Thermal Liquid Heaters. International Boiler Works Co.

27 Remote-Reading Gages. Latest designs in remote-reading liquid level gages described in bulletin from Jerguson Gage & Valve Co.

28 Vertical Turbine Pumps. 72-page hand-bound book "Answers to Your Questions About Layne Vertical Turbine Pumps" is offered by Layne & Bowler, Inc.

29 Process Instruments. New brochure from Leeds & Northrup presents all L&N instruments for chemical process applications.

30 Flow Meters. Calibration curves, float properties table, flow unit conversion table are contained in bulletin from Matheson Co.

31 Mist Eliminators. Metex mist eliminators give positive control of liquid carry-over in all processing equipment. Metal Textile Corp.

(Continued on page 70)

✓ **CHECK** *your Data Service requests on the handy postcard on page 61 to*

▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

DEVELOPMENTS OF THE MONTH *(Continued)*

105 Pre-assembled Pilot Plant. New pre-assembled pilot plant can be shipped intact, including all valves & piping & can be put into operation simply by connecting power & water lines & installing the instruments (which are packed separately to prevent breakage).

Design of the unit is based on specified physical properties, such as specific gravity, viscosity, boiling point, heat of reaction, incipient reaction temperature or other laboratory data. Both endothermic & exothermic reactions can be controlled quickly & accurately by automatic brine cooling & hot liquid heating systems which serve the reactor.

Such a unit, including a 35-gal. stainless steel reactor, heating & cooling systems, feed tank, condenser, decanter, two receivers, & all connections, controls & instruments, costs in the neighborhood of $25,000.

Detailed information available from manufacturer, Industrial Process Engineers.

(Continued on page 70)

CONTROLLED PRESSURE AT 100,000 PSI!

Superior super pressure quality tubing has been used to handle internal pressures from 15,000 to 100,000 psi—offers high fatigue strength, high chemical resistance, high pressure resistance

Safe and efficient service at extremely high pressures makes Superior super pressure tubing preferred for hydrogenation process equipment, high pressure autoclaves, and pilot plant installations in chemical and oil refining plants.

Superior produces this tubing from specially selected raw materials which have had the inside surfaces conditioned to remove fissures and other defects. In processing, special degreasing operations are performed on the tubing, and the inside diameters are sand blasted to insure a clear, smooth surface.

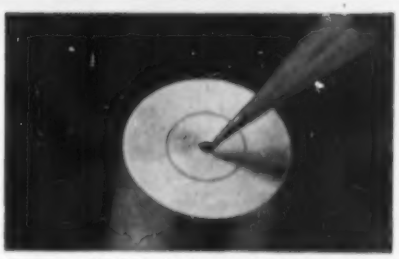
Two types of Superior super pressure tubing are available: a single wall mechanical tubing and a double wall, or composite unit, made from two thinner tubes.

Super pressure tubing is produced in an annealed condition and in ⅛ hard temper, and to mechanical properties specified by the customer.

This tubing is offered in the austenitic stainless steels, Types 304, 316, 321 and 347, and in AISI 4130 alloy steel. It is produced in sizes ⅛" OD x 1/16" ID up to ¾" OD x ⅛" ID. Minimum order quantity for mill production is 50 ft. per size and analysis.

Superior rigidly inspects all super pressure tubing for defects such as fissures by visual and microscopic inspection methods. Each length is hydrostatically tested to 5000 psi—upon request, up to 60,000 psi.

If you have a tubing problem in high pressure processing—or of any other nature—call on Superior. Write Superior Tube Company, 2011 Germantown Ave., Norristown, Pa., for Data Memorandum 22.



The composite type stainless super pressure tubing offers the advantage of having the inner and outer tubes independently worked to mechanical property requirements and of different alloys being combined for strength and corrosion resistance.

SUPER PRESSURE TUBING MINIMUM BURSTING PRESSURES FOR AUSTENITIC STAINLESS STEELS AND 4130 ALLOY STEEL

	MAXIMUM WALL			
OD	.053	.095	.156	.218
⅛	*97,200 88,400			
¼	*40,200 34,800	82,000 73,000		
½	*17,400 15,000	33,500 29,100	62,500 54,000	
⅝	*13,600 11,800	25,000 21,600	47,600 40,300	72,600 63,000

*Top figures all Austenitic Stainless Steels
Bottom figures all 4130 Alloy Steel

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010" to ⅝" OD—certain analyses in light walls up to 2½" OD

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331

equipment-

32 Instrument Index. Minneapolis-Honeywell offers an index of Industrial Division literature covering catalogs, bulletins, specification sheets, data sheets, illustrated lectures, and articles.

33 Mix-Mullers. The Simpson Mix-Muller is used in the preparation of electronic porcelain, tile, structural clay and brick, refractories, etc. Bulletin from National Engineering Co.

34 Heating Elements. "Hot Rod" Crystolon heating elements, product of Norton Co., offer longer life in electric furnace and kiln applications. Brochure.

35 Instrument Applications. Reprints of two articles—"pH Control in Industrial Waste Treatment" and "Practical Applications of Flow Colorimetry" available from Beckman Instruments, Inc.

36 Low-Output Mixers. The Oakes Continuous Automatic Mixer was designed for plants with relatively low rates of production. 28-page brochure. E. T. Oakes Corp.

37 Bronze Pumps. Capacities and specifications of complete line of bronze pumps given in catalog from Oberdorfer Foundries, Inc.

38 Gas Chromatography Instrument. Features and specifications of the Perkins-Elmer Model 154-B Vapor Fractometer discussed in 16-page brochure.

39 Circumferential Seal. The Koppers Co. circumferential seal gives low power consumption, low leakage rates, and longer efficient seal life.

40 Process Columns. Columns of glassed-steel and alloy construction in both tray and packed design described in 8-page bulletin from the Pfaudler Co.

41 Feeders. The Com-Bin Feeder, made by Pulva Corp., is specially designed for continuous feeding of sticky, mastic materials. Catalog.

42 Fertilizer Processing Equipment. Ammoniators, granulators, dryers, coolers, air handling systems, and pilot plant equipment are described in bulletin from Edw. Renneburg & Sons.

43 Metal Detector. The RCA Metal Detector can handle all kinds of tramp metal —magnetic and non magnetic. Brochure from Radio Corp. of America.

44 Suspended Centrifuge. A completely automatic suspended centrifuge for chemical, pharmaceutical and food processing industries in production at the Fletcher Works. Literature.

45 Centrifugal Air Washer. The Ducon Centrifugal Air Washer, UW-4, is ideally suited to a wide range of applications in industrial dust control and recovery. Bulletin from Ducon Co.

46 Multi-Wash Collector Data. Capacities, dimensions and approximate weights given in data sheet from Claude B. Schneible Co. Advanced design.

47 Entrainment Separators. Schuylernit entrainment separators are widely used in the petroleum, chemical, food processing, sugar and gas industries. Brochure from Schuyler Manufacturing Corp.

48 Steam Jet Vacuum Pumps. Sizes, dimensions, performance characteristics of three, four, and five stage steam jet vacuum pumps and vacuum boosters given in bulletin from Schutte & Koerting Co.

49 Compacting Presses. 24-page comprehensive catalog from F. J. Stokes describes compacting presses with capacities from 5 or 6 pieces per minute up to 4,000 per minute.

50 Explosion-Proof Motors. Rating and dimension tables, horsepower frame chart included in new bulletin from Allis-Chalmers.

51 Fluid Transfer Systems. Flexible hose links combined with "snap-on" hose couplings replace multiple-valve installations. Titeflex, Inc. Literature.

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▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

52 Process Equipment. U. S. Hoffman Machinery Corp. offers folder describing blowers, exhausters, pneumatic systems, filters, flotation equipment, separators, stills, tubular pipe and fittings.

53 Corrosion-Resistant Pumps. Vanton Pump & Equipment Corp. announces new pump in which body block and liner are of fluorocarbon materials which resist corrosion up to 300° F.

54 Vacuum Pumps. All types of tubejet vacuum pumps are made by C. H. Wheeler. Illustrated bulletin.

materials-

55 Mechanical Packing. 246 types of mechanical packing for every industrial service described in condensed catalog from Belmont Packing & Rubber Co.

56 Silicon Chemical Intermediates. Four new organo-functional silanes now available from Union Carbide and Carbon Corp. Many chemical process applications. Literature.

57 Pipe Insulation. 40-page catalog on Unibestos Pipe Insulation. Application instructions, charts and tables giving physical and thermal characteristics. Union Asbestos & Rubber Co.

58 High Pressure Tubing. Super-pressure tubing, made by Superior Tube Co., gives controlled pressure at 100,000 lb./sq.in. Available in stainless and alloy steels. Bulletin.

59 Wash Primers. 12-page booklet on Butvar (polyvinyl butyral) and Formvar (polyvinyl formal) for corrosion-resistant wash primers available from Shawinigan Resins Corp.

60 Rare Earth Data. Data sheet giving properties of high-purity rare earths. Oxides, salts, resinates, hydrides, metallic forms. St. Eloi Corp.

61 Resin Review. Rohm & Haas Co. offers Vol. VI, No. 3, of their Resin Review. Many articles of interest to users of synthetic resins.

(Continued on page 72)

DEVELOPMENTS OF THE MONTH *(Continued)*

106 Operatorless Industrial Tractor. Barrett-Cravens Co. maker of the Guide-O-Matic electronic industrial tractor, has announced a new optical guidance system. The new method requires only a painted line or a white tape on the floor, as shown in the illustration.

Light emanating from a small, low-powered bulb in the "sniffer" box reflects from the white tape or paint on the floor and actuates photo-electric cells in the sniffer box. Thus, the tractor steers accurately in the direction of the line at all times. Details available. Circle number 106 on Data Service card.

(Continued on page 72)

A NEW BOOK...and a new way to select pipe insulation for greatest savings

Now there's a fast, easy way to select economic thickness of pipe insulation accurately...efficiently. It's featured in the new Unibestos Catalog. This handy guidebook introduces a new simplified method based on a special "J" factor. The easy-to-use "J" index eliminates most of the complicated, time-consuming computation required by other methods.

Selecting Unibestos is a smart move, too. Made of Amosite asbestos, Unibestos® protects against heat loss with only *single-layer application.* Strong interlacing fibers seal in more heat at the difficult joints than any other single- or double-layer insulation.

Built strong to stay strong, yet easy to miter and cut, Unibestos goes on the most difficult fittings easily... reduces application costs wherever it's used. Available in sectional form through 44" O.D.

Write today for your copy of the new 40-page UNIBESTOS CATALOG

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Company.....

Address.....

City.....*Zone*.....*State*.....

materials-(Cont.)

62 Insulation Case Studies. Six case study reports on insulation problems in the petrochemical and petroleum industries. Pittsburgh Corning Corp.

63 Hydrazine Solution. Scav-Ox, new 35 per cent hydrazine solution for removing oxygen from boiler feedwater, described in 16-page booklet from Olin Mathieson Chemical Corp.

64 Spectrograph Chart. Characteristics of secondary X-ray beams for elements from magnesium to californium. North American Philips Co.

65 Chlorosulfonic Acid Abstracts. List of 30 abstract references includes physical and chemical properties, analysis, typical reactions, handling and corrosion characteristics, toxicity and safety data. Monsanto Chemical Co.

66 Adsorbents for Platinum Catalyst Systems. Special materials to prevent catalyst poisoning described in 12-page technical bulletin. Minerals & Chemicals Corp.

67 Carbon Bibliography. New publication, "An Annotated Bibliography of the Literature and Patents Relating to the Production of Carbon by the Decomposition of Carbon Monoxide," is offered by Mellon Institute.

68 Lead Oxide Data. Safety data sheet on lead oxides available from Manufacturing Chemists Association.

69 Polystyrene History. Technical service bulletin on history and development of commercial polystyrene production. Koppers Co.

70 Tungsten & Titanium Carbides. A 24-page bulletin from Kennametal, Inc. gives properties and applications of carbides of tungsten, titanium, and other metals.

71 Plastics. Kaufman Glass Co. offers 38-page catalog and price list covering wide line of plastics.

72 Aluminum Insulation. Illustrated manual from Kaiser Aluminum gives detailed information on aluminum insulation jacketing for tanks, vessels, & piping systems.

73 Bromine. Comprehensive product booklet, offered by Dow Chemical Co., covers properties and methods of handling bromine.

74 Column Packing. Stedman packing, made of stainless steel wire cloth, makes possible lower tower heights in many applications. Packed Column Corp. Bulletin.

75 Diatomaceous Silica Products (Celite). 46-page booklet on flatting agents, pigment extenders, filter aids for the finishes industry. With 41 paint formulas.

76 Catalysts. Houdry Process Corp. offers bulletin on catalysts of all types for the chemical process industry.

77 Caustic Soda Manual. 40-page manual "Caustic Soda Engineering and Handling Guide" from Hooker Electrochemical Co. Many graphs, charts, and tables.

78 Glycerine Data. Commercial grades, definitions, specifications, test methods, shipping and storage requirements. A 19-page booklet from Glycerine Producers Association.

79 Lithium Compounds. Chemical and physical properties of 16 compounds of lithium compiled in loose-leaf form. Foote Mineral Co.

80 Plastic Gasket Material. Vacuum line sealing leakage reduced to a minimum by new plastic gasket material. Literature from Flexrock Co.

81 Thiovanic Acid. Properties, specifications, typical reactions, suggested uses are contained in folder from Evans Chemetics, Inc.

82 Nonionic Water Softener. An 8-page booklet from Emery Industries, Inc. gives properties of Emersoft, a new nonionic softener.

83 Polyglycols. Pilot plant production of polyepichlorohydrin, polystyrene glycol, and polybutylene glycol is announced by Dow Chemical Co. These new products available in small quantities. Literature.

84 Resin Plasticizer. 5-page technical bulletin from Diamond Alkali describes properties of Chlorowax LV and its use as a secondary plasticizer for vinyl resins.

85 Flat Glasses. Properties, applications, and characteristics of Corning flat glasses presented in new illustrated bulletin. Corning Glass Works.

86 Industrial Chemical Data. Technical data sheet covering properties of alcohols, amines and ammonia, esters, and other chemicals. Commercial Solvents Corp.

87 Molybdenum Chemicals. Climax Molybdenum Co. offers bulletin describing chemical applications of molybdenum, including catalysts, fertilizers, pigments, and lubricant additives.

88 Organic Chemicals—Data & Index. Condensed data on applications and physical properties of more than 335 organic chemicals presented in tabular form with index. Carbide and Carbon Corp.

89 Activated Charcoal. Comprehensive catalog offered by Barnebey-Cheney Co. includes illustrated technical sheets, magazine reprints, and detailed reports on the use of activated charcoal.

90 Expanded Foam Polyethylene. Agilene-F, expanded foam polyethylene, is now available from the American Agile Co. in rings, blocks, rods, and sheets. Literature.

91 Hydrogen Peroxide Storage. Detailed information on new equipment and simplified handling methods for storing bulk hydrogen peroxide. New booklet from Allied Chemical & Dye Corp.

92 Flexible Plastic Tubing. 28-page booklet gives physical properties and chemical resistances in chart and table form. U. S. Stoneware Co.

93 Epoxy Plasticizer. Physical properties, compatibility, suggested applications of Drapex 3.2 contained in booklet from Argus Chemical Corp.

94 Plastic Coating. "Super 5300" coatings protect against a wide range of acids, alkalies, salt solutions and complex chemical compounds. Metal & Thermit Corp.

95 Paint Resins. Booklet from National Starch Products describes series of resins for use in paints and primer sealer formulation.

96 Polymeric Plasticizer. Eastman polymeric plasticizer NP-10, for use in the compounding of polyvinyl chloride, has recently been introduced by Eastman Kodak Co.

✓ **CHECK** *your Data Service requests on the handy postcard on page 61 to*

▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

DEVELOPMENTS OF THE MONTH *(Continued)*

107 Pocket pH Meter. A versatile, low-price, pocket-size pH meter that is accurate, dependable, easy to operate & which uses a combination electrode is offered by Beckman Instruments, Inc.

Range of the meter is from 2 to 12 pH. The single electrode combines both reference & glass electrodes. Instrument has a "memory" dial for use in standardizing. Operates on simple, inexpensive batteries such as are used in flashlights & hearing aids.

Further information available from the manufacturer. Circle number 107 on Data Service card.

PROGRESS at Proctor for THE WORLD OF CHEMICALS

Proctor engineering and production of quality drying equipment has blazed a trail for the chemical process industries

5 DECADES OF PROGRESS

1900	Tray Truck Dryers
1923	Job-Engineered Continuous Conveyor Dryers
1923	Chemical Loop Dryers
1934	Fin Drum Feed
1937	Granulator
1938	Roller Extruder
1938	Scoring on Filter
1953	Spray Dryer

In over five decades of improvement in drying methods, Proctor has steadily advanced the continuous processing of chemicals and allied products, and has thus paved the way for growth, expansion, and diversification throughout the industry.

The success of Proctor continuous drying systems in the chemical industry alone, demonstrates Proctor's ability to produce the best drying equipment for rugged, dependable service. Through the development of test-methods and test facilities, through an understanding of the needs of the processor, through engineering experience and manufacturing skill, the name Proctor has become synonymous with quality drying the world over.

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The new Paracoil Oil and Water Coolers—Type "P" Exchangers—are solving production problems throughout industry. In addition to prompt delivery, users are finding these advantages:

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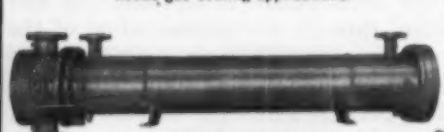
Water Coolers – for internal combustion engine and compressor jacket water, electrolyte solutions, brine solutions, boiler blow-down, condensate, etc.

For stationary and marine service



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CONTINUOUS OIL-COAL CHEMICAL REFINERY NEARS COMPLETION

World's first completely continuous processing plant for cresylic acid, cresols and phenols is nearing completion at the Newark, N. J., headquarters plant of Pitt-Consol Chemical Co.

Full production at the pioneering oil-coal chemical refinery is scheduled for January, 1957. Employing a continuous extraction process developed during years of research in coal-chemicals refining by the new chemical company's parent firm, Pittsburgh Consolidation Coal Co., the new refinery will triple Pitt-Consol's production of cresols, cresylic acids, phenol, phenolic resins and molding powders.

Continuous oil-coal chemical refinery of Pitt-Consol Chemical Co. going up in Newark, N. J.

While the development work on the new process was performed with coal-chemicals, the new plant will use as its raw materials petroleum refinery liquids which were formerly disposed of as waste. Products of higher purity and more uniform quality are expected to result from the new process than was possible with older batch processing methods.

Full operation of the Newark refinery is expected to make Pitt-Consol one of the top ranking producers of cresylics. A larger refinery, which is planned to produce substantially the same range of chemicals from liquids derived from low-temperature carbonization of coal, is planned to go into operation at Cresap, W. Va., by late 1958. Combined output of the two plants will total about 60 million pounds annually by 1960, which would make Pitt-Consol the largest manufacturer of cresylic chemicals.

The new Tacony (Philadelphia), Pa., plant of Columbian Carbon Co. is the company's third plant for the manufacture of colloidal dispersions of carbon black.

THE SHARPLES SUPER CLASSIFIER

The Ideal Air Vortex Classifier

- ★ **Ultra-sharp cutpoint with high capacity**
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- ★ **Unmatched efficiency**
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The Sharples Super Classifier is achieving heretofore unattainable standards of performance in the classification of dry powders. A copy of Sharples Bulletin 1280 will be sent upon request.

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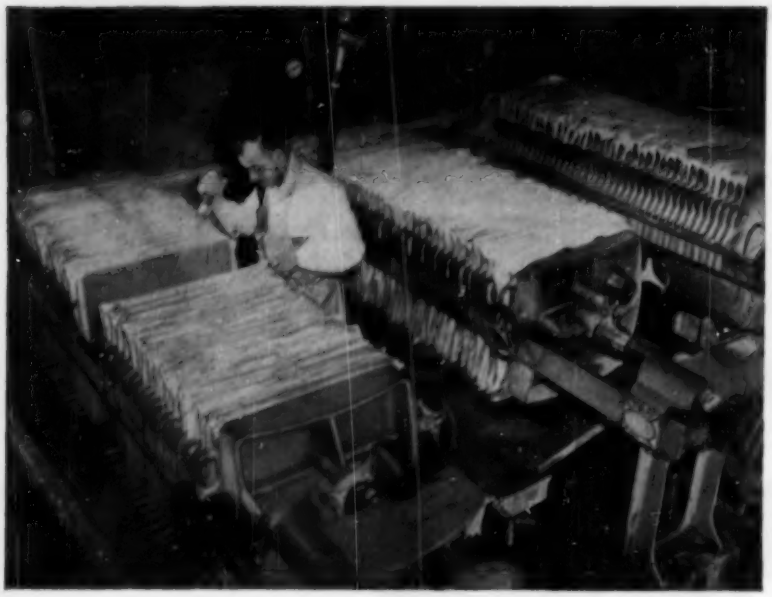

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Shriver Filter Presses offer

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- ✓ Perfect clarification regardless of nature of slurry, even the most viscous materials.
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- ✓ Suitable for filtration over widest pressure and temperature range.
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- ✓ Filter plates made of any suitable metal, wood, plastic, plastic-coated or electroplated metal.
- ✓ Filter media of any type — textile or metal cloth, paper, etc.; also any filter aids.

When considering the right filter for your process, bear the above factors in mind. Remember, Shriver Filter Presses are the most widely used of all batch pressure filters—and for good reason: Low investment cost, low floor space per unit of filtering area, widest range of usefulness.

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INDUSTRIAL NEWS

An ammonia plant of 180 tons/day capacity will be built by the Texas Co. at its Lockport, Ill., refinery. Construction will begin in the fall, the plant will have facilities for converting a substantial part of the ammonia to nitrogen solutions. □

A $7,700,000 contract for the construction of a large asbestos ore milling plant in the Black Lake-Thetford Mines district of Quebec, has been awarded to F. H. McGraw Company of Canada, Ltd., by Lake Asbestos of Quebec, Ltd., a wholly-owned subsidiary of American Smelting and Refining Co.

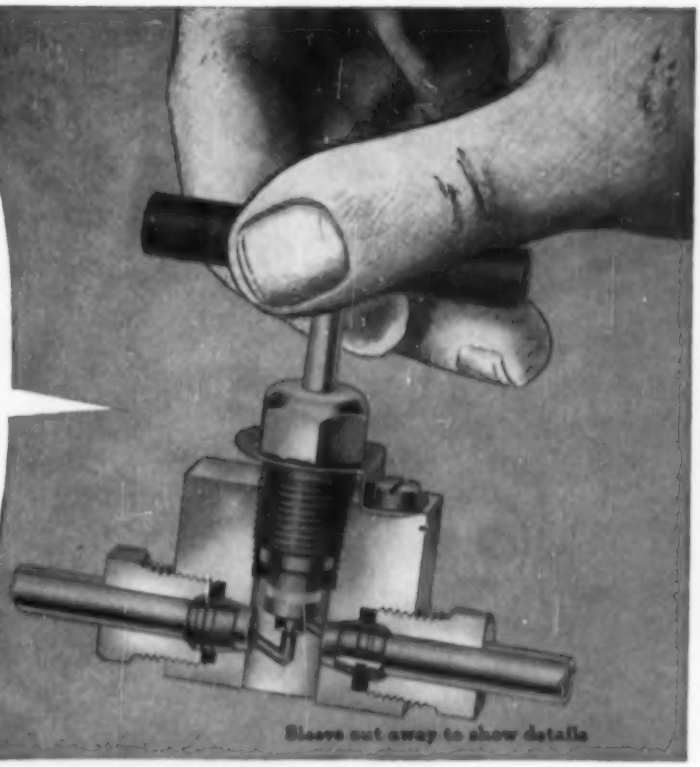
Work is underway on the plant that is expected to produce 5000 tons of ore per day when it is finished in early spring of 1958. Approximately 100,000 tons a year will be produced. □

In an effort to improve the recovery of petroleum from oil fields, Gulf Research & Development has undertaken an expanded research program involving 150 scientists, engineers and technicians. Two new buildings, costing about $1.5 million, will house these activities. Specific aims of the program include increasing the percentage of petroleum recovered from oil formations, and bettering both the speed and the economy of drilling wells, producing oil and gas, and transporting oil and gas. □

Although this new five-story-high pilot plant unit of Esso Research and Engineering at Linden, N. J., has been built to supplement the company's laboratory studies of the fluidized-solids technique of making gasoline, not one drop of petroleum will pass through it. Instead, compressed air (at the rate of 8,000 cubic feet a minute) passes through the giant column, serving as an adequate substitute for oil feed stocks since the unit is aimed at engineering research rather than process research.

For
Fast Assembly
To 10,000 PSI

AUTOCLAVE SPEEDVALVES *and* FITTINGS



INSTALLED IN 3 STEPS

1.
Cut tubing to desired length. Remove burrs.

2.
Slip adapter nut and then sleeve onto the tubing.

3.
Insert tubing into the valve as far as it will go. Tighten the nut.

Easy, fast tubing assemblies *to 10,000 p.s.i.* are now available with Autoclave Speedvalves and Fittings. The valves are quickly installed in 3 steps shown at left. No pipe threading . . . no tube reaming . . . no seal welding. Every joint is a union connection. The result: a gas-tight seal to 10,000 p.s.i. in less time, with fewer operations, at lower cost.

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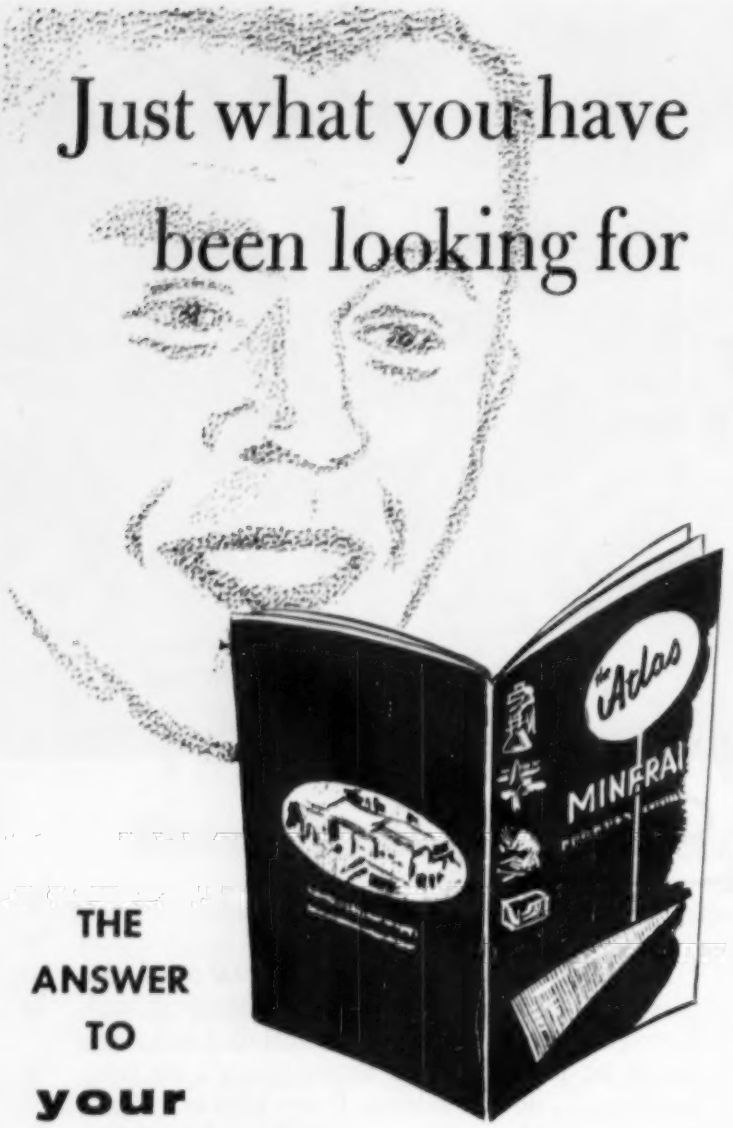

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A completely new sixteen page bulletin on corrosion proof materials of construction. . . . Individual sections on CORROSION PROOF CEMENTS, PROTECTIVE COATINGS, TANK LININGS and RIGID PLASTIC STRUCTURES and PIPE . . . also sections including engineering design and corrosion resistance charts.
This bulletin is filled with valuable information on 18 materials that can be used to give you plant-wide protection from corrosion.

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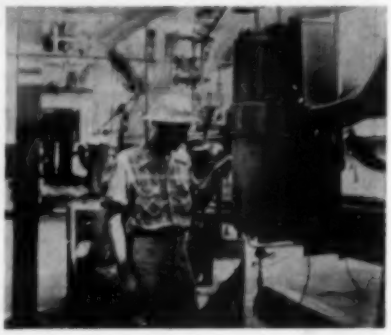
TECHNICAL REPRESENTATIVES THROUGHOUT THE UNITED STATES

INDUSTRIAL NEWS



This continuous infrared analyzer is on duty 24 hours a day keeping check on the purity of commercial ethylene produced at Gulf Oil's Port Arthur, Tex., refinery. Manufactured by Leeds & Northrup, the analyzer, and its panel-mounted recorder, monitors impurities in the stream so that if the analyzer should detect a predetermined percentage of impurities, operators can promptly divert the stream to the plant's fuel system before it contaminates the pipelines. This is vital at this Gulf plant since the ethylene stream runs from the plant directly into some 130 miles of pipelines to various chemical companies in the area.

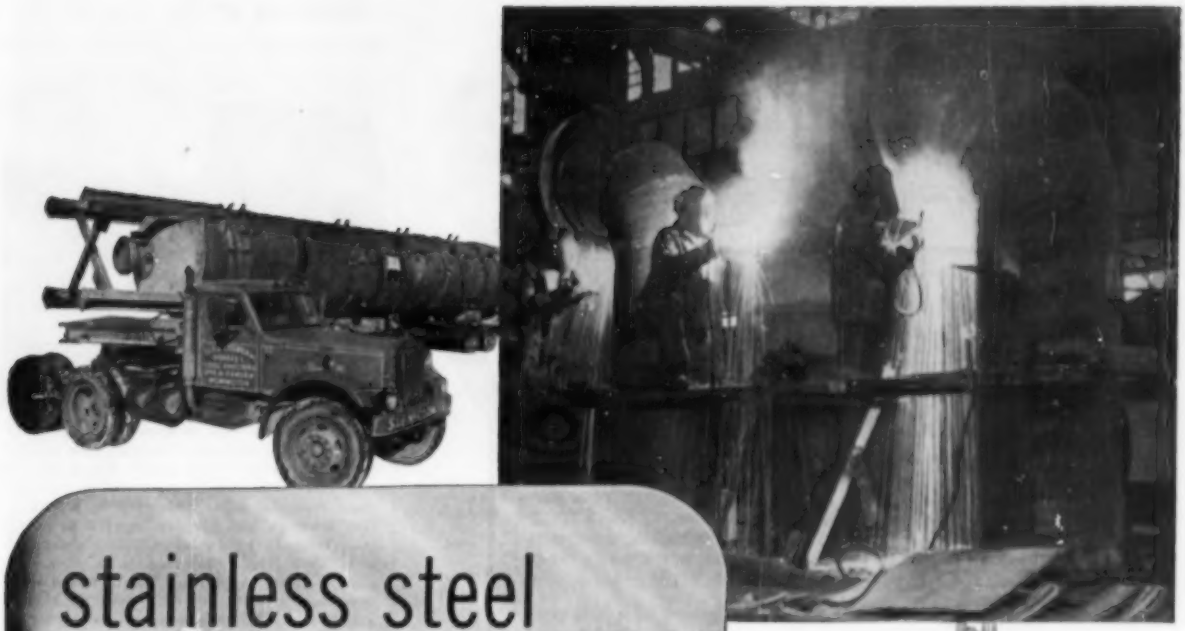
A new long range planning section has been added to the Commercial Development Dept. of General Aniline's Dyestuff and Chemical Division. The new organization is expected to help in the planned growth and expansion of the company. □

The boards of directors of West End Chemical Co. and Stauffer Chemical Co. have approved a plan of merger of West End into Stauffer. Formal agreement is expected to be adopted and submitted to the stockholders in the near future. □

Intended primarily to supply space for the technical service group assigned to agricultural chemicals, a new two-story addition is being added to Shell Chemical's technical service laboratory in Union, N. J. □

New facilities to be installed at Du Pont's Clinton, Iowa, cellophane plant will provide about 10 million pounds additional cellophane capacity by the middle of 1958, and new construction at "Mylar" polyester film plant at Circleville, O., will increase "Mylar" capacity by 50%. □

Additions to Glidden Co.'s Adrian Joyce titanium dioxide plant will quadruple the plant's capacity by 1957. Completion of the additions was scheduled for 1960 at an estimated cost of $30 million, but the company has recently decided to accelerate the project.



stainless steel holds the answers

Every industry that works with steel has its special problems of the proper steels for every job . . . more and more industries are finding that Stainless "holds the answers" to their problems.

Take the petroleum and chemical industries for instance. They demand resistance to corrosion, to abrasion, high temperatures, cold temperatures, scaling and hydrogen blistering. Solid stainless can do the job. But, in some equipment, stainless cladding can answer the problems . . . and cut costs as well.

Sun Ship knows how to fabricate stainless and the other special alloys. They have the facilities and experience. Large jobs or small jobs will receive prompt attention.

Our Sales Engineering Department will be glad to discuss with you any problems to which our Alloy Products Shop may hold the efficient and economical answer.

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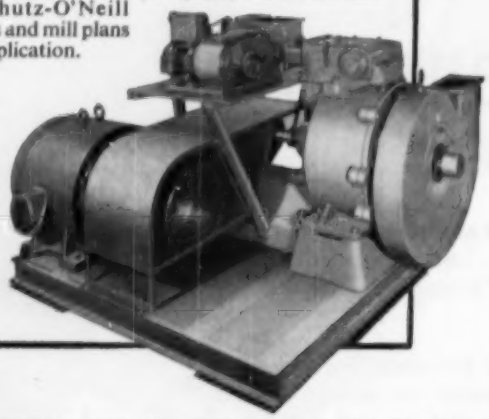
SCHUTZ-O'NEILL PILOT PLANT uses a standard production model 16" Superfine Pulverizer, which provides up to 100 different pulverizing set-ups with a grinding range from 40 mesh to 5 microns.



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AIR CLASSIFIERS
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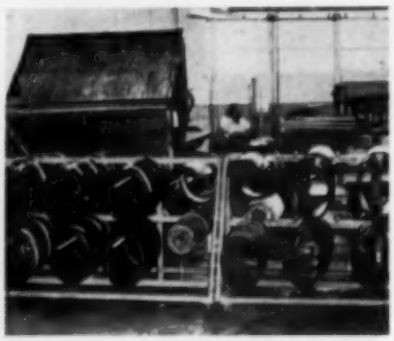
INDUSTRIAL NEWS



An entirely new type of automobile tire, made from butyl synthetic rubber created from refinery gases, has demonstrated specific safety features and other advantages over present synthetic tires. Produced under pilot plant conditions by Esso Research and Engineering, the new tires have immunity to atmospheric or chemical attacks which cause other rubbers to crack, considerably smoother riding comfort, a low noise level, and will stop the car much much more quickly than GR-S-natural-rubber mixture tires.

A $1 million catalytic desulfurization unit will be engineered and constructed by the Fluor Corp., Ltd., for Great Northern Oil Co. Field construction has already begun at Great Northern's Pine Bend, Minnesota, refinery, completion is scheduled for early December 1956. □

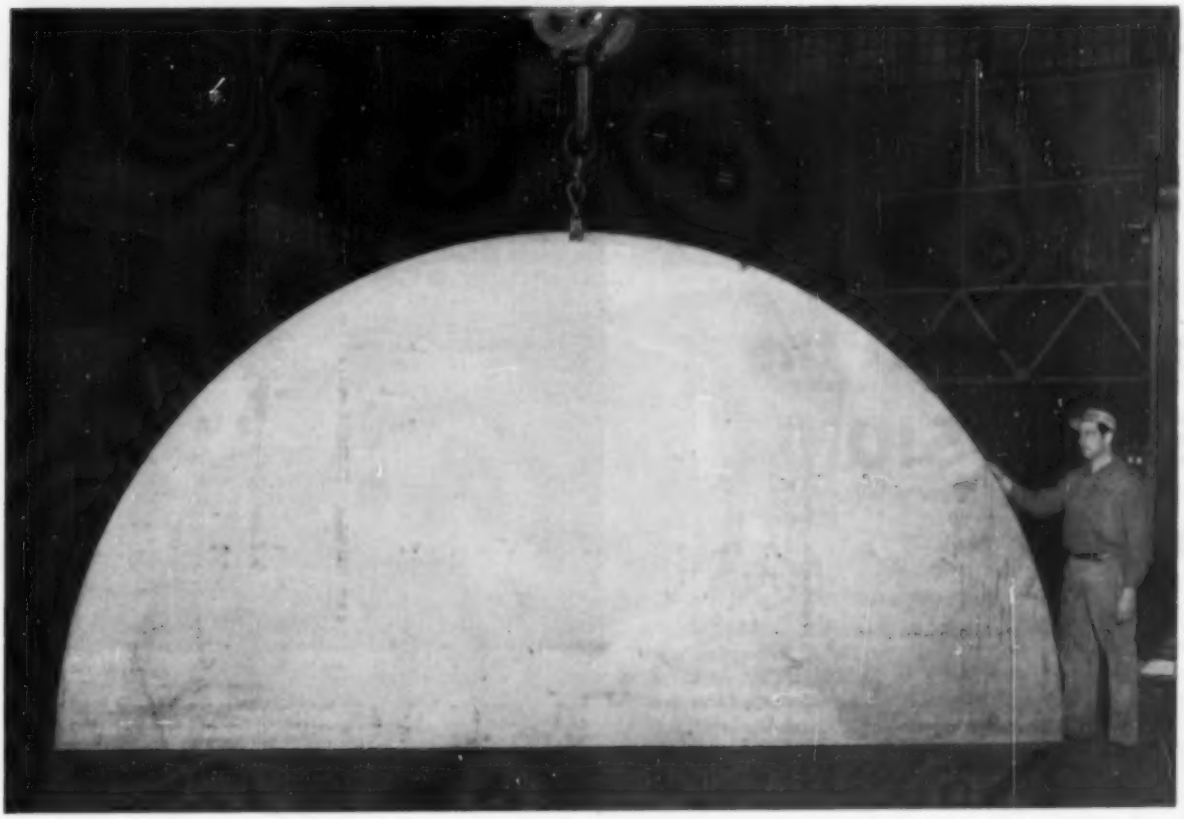
A new $2.5 million plant to manufacture specialty acrylic polymers will be constructed at Calvert City, Ky., by B. F. Goodrich Chemical Co. Expected to be completed in October, 1957, general contractor is Wigton-Abbott Corp. of Plainfield, N. J. □

Du Pont will build a new 40 million-pound-per-year Orlon acrylic staple and tow plant at Waynesboro, Va. The new plant will bring Du Pont's Orlon staple and tow capacity to over 100 million pounds a year. □

A 25,200 bbls./day residuum stripper will be built for Standard Oil Co. of California by the Fluor Corp., Los Angeles. Located at Standard's El Segundo refinery, the unit is scheduled to go on-stream in April, 1957. □

Walworth Co., manufacturer of valves and fittings, has acquired all the capital stock of Grove Valve and Regulator Co., and Grove Controls, Inc., both of Oakland, Cal. □

Pennsalt Chemicals is nearly doubling the size of its Chicago Heights, Ill., blending, packaging and warehousing plant. □



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Here's how Carlson *specialized service* in stainless plate worked on this job.

The illustration shows one of two segments of a tank head blank. Made of 1" thick, Type 302 stainless steel, the head blank measures 210" in diameter and weighs approximately 9000 pounds. Each segment was produced so accurately the customer did not have to "true up" the abrasive cut straight edges before welding the two segments together. This meant the customer had what he wanted, the way he wanted it—produced to his exact requirements.

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More than once we've helped a customer do his job easier, quicker and at lower cost by efficient planning and expert use of specialized equipment. This experience can work to your advantage, too. You can buy *exactly* what your specifications call for—and nothing more. This saves freight charges on material you cannot use. It also saves the cost and trouble of handling scrap in your shop. And you can set up a faster production schedule based on receiving what you want, when you want it.

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A Pittsburgh Meeting Report

conquest of the EXPLOSION hazard

An explosion of 800 pounds of coal dust issues from the main entry of the experimental coal mine of the Bureau of Mines, Dept. of the Interior, at Bruceton, Pa. Demonstration was witnessed by members of A.I.Ch.E. as a sidelight to the Pittsburgh meeting in September.

What can the chemical engineer do to recognize and deal with explosion hazards in his day-to-day work? A major A.I.Ch.E. symposium at Pittsburgh discussed this and analyzed the prevention, minimization, and mechanism of dust explosions, mist explosions, and explosive problems of jet fuels, particularly at high altitudes.

New chemical processes and techniques bring new advantages but they also bring new dangers. Low-temperature operations, for example, have encountered considerable explosion hazard. Clearly, theoretical and experimental work on the behavior of explosible materials is not merely of academic interest; the safeguarding of millions of dollars worth of equipment is involved.

The Practical Side

What can the practicing chemical engineer do to recognize and deal with explosion hazards in his day-to-day work?

Safety consciousness is perhaps even more important for the chemical engineer in a small company than for one employed by a big company. In the latter case, a concerted effort is usually maintained to improve safety conditions. In many small companies, however, lack of personnel prevents the formation of a full-time safety department and such matters are left to the judgment of the individual engineer.

To appraise a new chemical engineering project from an explosion prevention viewpoint the symposium group recommended the following considerations:

1. What knowledge is available on the ignition limits and the explosive properties of the materials to be handled? In addition to the standard handbook data, a careful search should be made of the literature with special emphasis on recent work on the effect of pressure and temperature variations and on the catalytic effect of various types of metal surfaces.

2. If sufficient information on explosion limits is not available from any source, it may become necessary to run laboratory or even pilot plant tests under the actual proposed operating conditions. While this may sometimes be expensive and time-consuming, human life is the governing consideration.

3. What equipment is available for the prevention or minimizing of explosion damage? The chemical engineer should be thoroughly familiar with flame quenching or arresting devices, emergency pressure relieving measures such as rupture disks or explosion diaphragms, inerting systems, flame failure controls, and automatic interlocks, among other equipment.

4. What standards and codes are in common use in the industry? In this connection, mention should be made of the outstanding work of the American Standards Association and of the National Board of Fire Underwriters.

5. If the engineer is engaged in equipment design work, he should bear in mind that it is much easier to incorporate safety features into the original design than to add them later when the equipment has already been installed.

6. What provision is being made for scheduling of operating maintenance? This is essential if vigilant control is to be exercised over potential fire and explosion hazards.

New Process—New Data

Data on explosion limits given in standard handbooks still currently available were largely obtained at normal conditions of pressure and temperature. Indiscriminate use of such data when working at extremes of pressure or temperature can be misleading and perilous. Since the basic mechanism of ignition and explosion phenomena is not sufficiently understood, extrapolation of existing data is not generally feasible. Recent work shows conclusively that explosion limit curves often pass through completely unexpected maxima and minima at extremes of pressure and temperature.

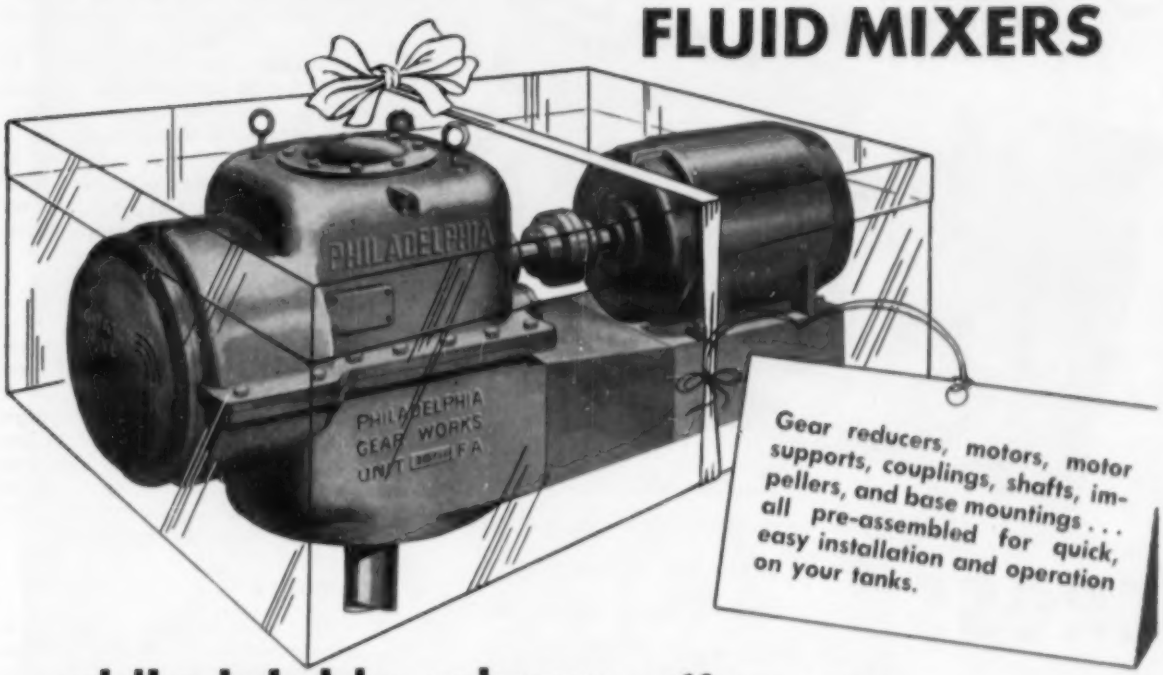
One hundred per cent explosion prevention can rarely be attained. Venting through properly designed ducts of varying sizes, shapes, and lengths can do much to minimize force and destructive power. Of equal importance are newly developed methods for the control of incipient and secondary explosions. These points were strongly brought out by Irving Hartmann of the U. S. Bureau of Mines in a paper which described recent work on the causes and prevention of industrial dust explosions.

Basic to the prevention of explosions, said Hamilton Lewis of Du Pont's Burnside Laboratory, is a comprehen-

(*Continued on page 84*)

today's TREND is toward

"Packaged" FLUID MIXERS



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Completely integrated "packaged" service. Philadelphia designs, and manufactures in one plant, every major component of these fluid mixers, except motors and bearings. As a result, through this one centrally controlled, thoroughly responsible source, you can obtain the complete solution to your fluid mixing problems.

Service-Rated Motors. Standard NEMA frame motors for any operating condition can be supplied. Special mountings, variable speed drives or special motors are available.

Quick-Change Gear Drives. Easily accessible, helical change-gear set allows ready selection up to 14 different standard speeds to meet your changing process needs. Spiral bevel gears of hardened steel are accurately lapped, assembled in matched pairs and micrometer tested for long, quiet operation. All drives are A.G.M.A. rated.

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Unitary Mechanical Shaft Seal. Positive leak-proof shaft seal for closed tank agitation gives long maintenance-free service life. When necessary, it can be installed and replaced in minutes with only a wrench. No special lifting equipment is needed.

Heavy Duty Shafts & Bearings. Extra large heavy-duty output shafting results in less shaft deflection at stuffing box or mechanical seal, steady operation of overhung mixer shafts. All bearings are oversize, with a generous service factor.

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EXPLOSIONS

(*Continued from page 82*)

sive study of ignition requirements for the materials or mixtures in question. Since the exact determination of ignition limits for all possible operating conditions is a practical impossibility, it is necessary, as far as possible, to avoid the existence of conditions which would permit the development or propagation of explosive reactions. As a last-ditch measure, if no possibility of preventing explosions exists, one must consider provisions for minimizing the effects of the worst conceivable occurrence.

Mists Same as Vapors

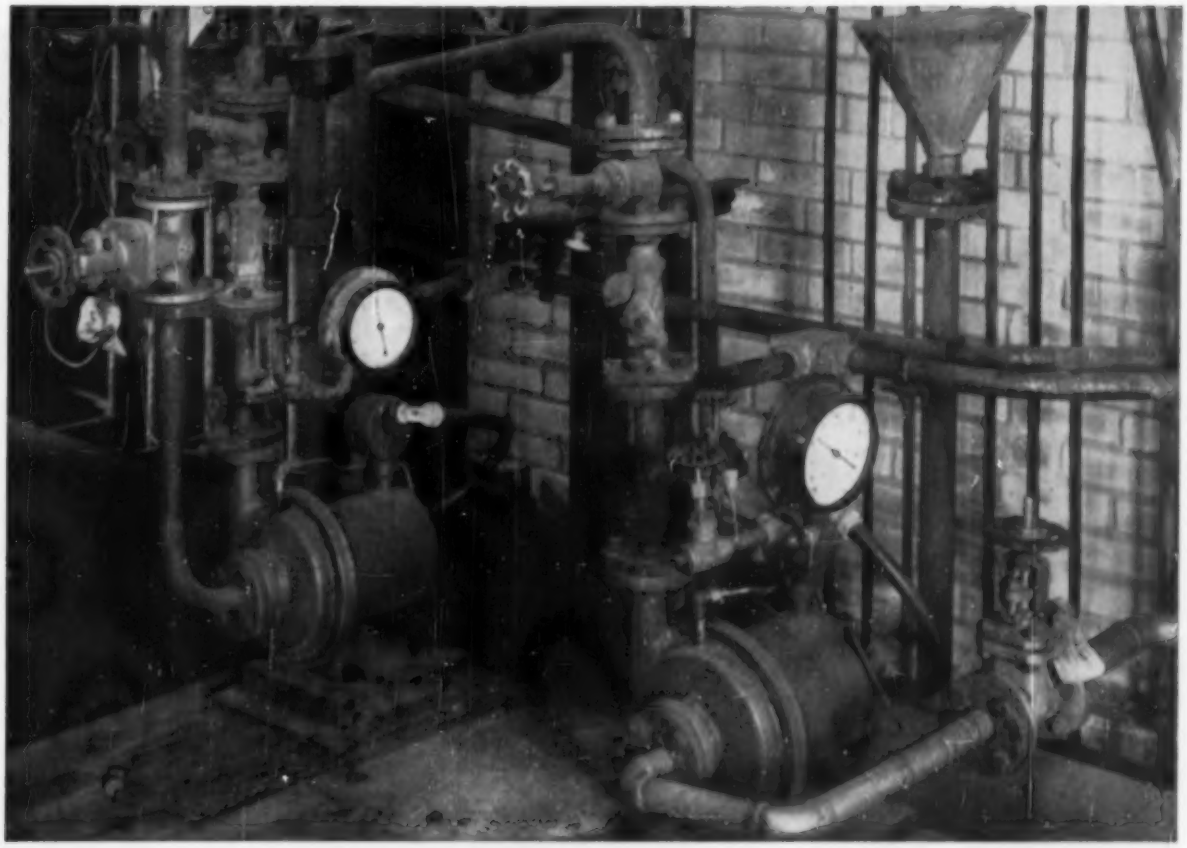
Condensed mists behave very closely as they would if the same fuel were present in the vapor form, according to John H. Burgoyne of Imperial College, London, England. However, with suspensions of larger drop size, there is an essential change in the mechanism of flame propagation, although explosibility properties remain fairly constant.

Pressure Effects

Operation of military jet aircraft at high altitudes has resulted in investigation of interest to chemical engineers contending with flammable hydrocarbons at low pressures. Experimental work carried out at the Univ. of Calif., reported by Paul Stewart and E. S. Starkman, has furnished at least partial answers to some of these questions. Ignition and flammability limits for mixtures of aircraft fuel vapor, oxygen, and inert gases were investigated at pressures equivalent to altitudes up to 60,000 feet and over a temperature range of 35 to 140° F. Results show wider flammability limits than hitherto reported. In addition, it has been shown that the presence of the liquid phase along with the gas phase further widens the limits.

Further work in an opposite direction has been carried out by Zabetakis, Scott and Kennedy of the Bureau of Mines. Equipment was designed and built which made possible the determination of flammability limits and spontaneous ignition temperatures at pressures up to 10,000 lbs./sq.in.

A new plant to machine, test and assemble Rockwell-Nordstrom Hypreseal valves will be built at Kearney, Nebr., for the Rockwell Manufacturing Co. To cost some $2 million, the plant is expected to be completed by midsummer 1957. These valves are used primarily by the oil, natural gas, chemical and chemical processing industries.



Canned pumps cut downtime...

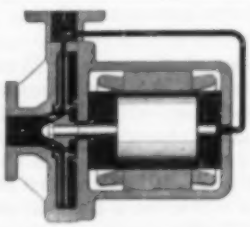
Leakproof Chempump helps avoid shutdowns at Publicker acetic acid plant

These two *Chempumps* are handling a mixture of alcohol, ethyl and propyl acetate and water . . . definite trouble makers for conventional centrifugal pumps. The men at Publicker say these pumps are doing a job that no other can handle.

Conventional centrifugals previously used couldn't hold this volatile, highly solvent mixture. Maintenance men had to tighten glands every few days, repack stuffing boxes twice a month. Leakage was expensive and hazardous . . . and downtime at this 24-hour-a-day plant was a really serious problem.

Installation of these two Series C *Chempumps* was the solution. One pump, on feed service, runs 24 hours a day, seven days a week. The other, a by-product pump, runs four or five days out of every 14. A simple bearing change once a year is the only maintenance required.

Perhaps your operation calls for a seal-less *Chempump*. For details, write to Chempump Corporation, 1300 East Mermaid Lane, Philadelphia 18, Pa. Engineering representatives in over 30 principal cities in the United States and Canada.



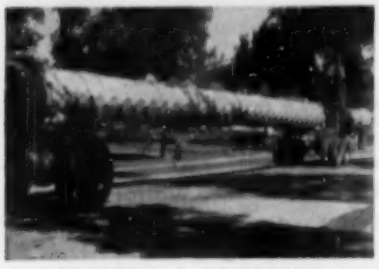
Chempump combines pump and motor in a single hermetic unit. No shaft sealing device required.

U. L. approved. Available in a wide choice of materials and capacity ranges for handling fluids at temperatures to 1000 F. and pressures to 5000 psi.

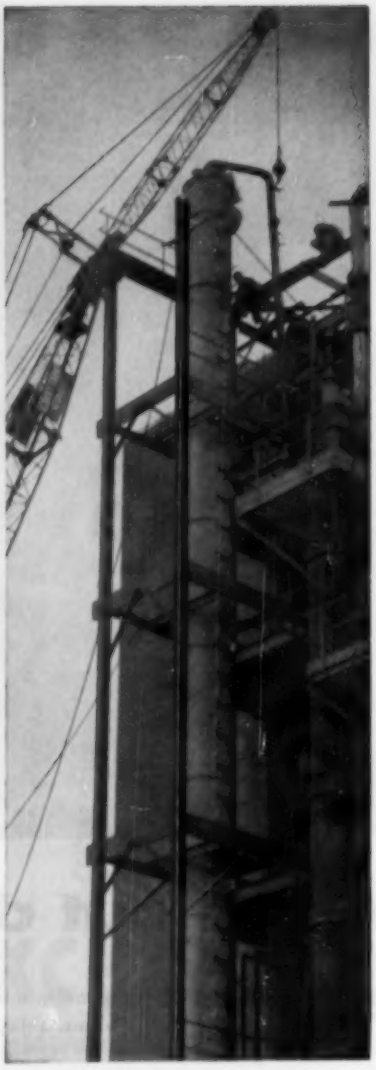
Chempump

First in the field...*process proved*

Line-up was checked with transit to hold close tolerances during welding. Tower passed rigid inspections, was Code stamped.



Motor freight saved time and cost.



Field erection went smoothly.

80-tray tower...by Downingtown

Complete mechanical design and fabrication by Downingtown Iron Works. 80 trays welded in shell. Tray flatness held to unusually close tolerance. Ten-inch handhole at each tray. Customer more than satisfied with performance of tower. Send now for Bulletin PF. See what we've done for others...learn what we can do for you on towers, pressure vessels, process equipment.

Diameter: 36″

Total Height: 92′ 6″

Shell Thickness: ⅝″, ½″ and ⅜″

Material: Carbon steel

80 trays, 45 bubble caps per tray

Downingtown Iron Works, Inc.

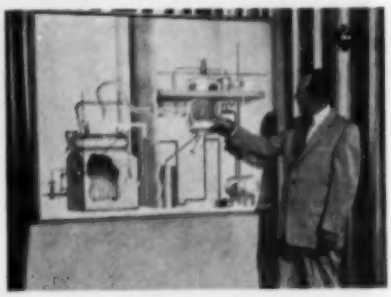
HEAT EXCHANGERS—STEEL AND ALLOY PLATE FABRICATION

1458 S. 66th St., Milwaukee 14 • 52 Vanderbilt Ave., Room 2032, New York 17 • 106 Wallace Ave., Downingtown, Pa. • 271 Hanna Bldg., Cleveland 15 • 936 W. Peachtree St., N.W., Room 144, Atlanta 9 • 208 S. LaSalle St., Room 765, Chicago 4 • 586 Roosevelt Bldg., Los Angeles 17

DOWNINGTOWN IRON WORKS Hackney

CONTAINERS AND PRESSURE VESSELS FOR GASES, LIQUIDS AND SOLIDS

INDUSTRIAL NEWS



Available free to any engineering society meeting, classroom, or other interested group, is a new film in color on the subject of Heat Transfer. Called "Heat Transfer—400°-750° F.," the new film was viewed by 200 chemical engineers at the A.I.Ch.E. national meeting in Pittsburgh. Produced by Dow Chemical, the film is aimed at practicing engineers, student engineers, and anyone interested in industrial process heating. It is being distributed by Modern Talking Pictures Service, Inc., 3 E. 54 St., New York City.

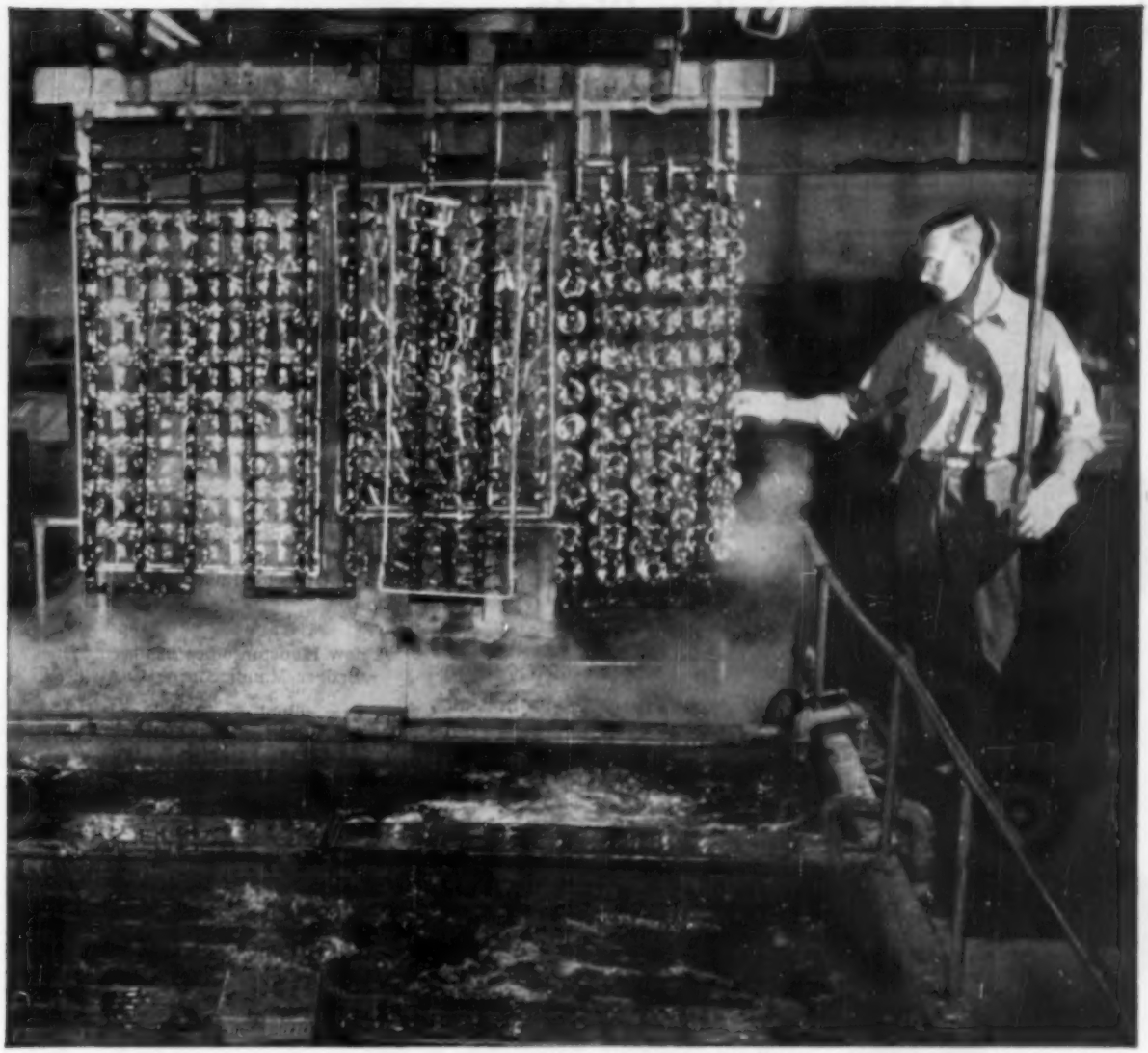
A new anti-knock compound manufacturing plant will be built in the San Francisco Bay area of California by the Ethyl Corp. □

Forty Russian turbo drills of various sizes have been purchased by Dresser Industries, Inc., Dallas. The company has also contracted for a shipment of French turbo drills. Dresser claims it now has the exclusive right to manufacture and market both Russian and French drills in this country. The foreign drills will be examined, tested and evaluated, and some features of their design will be incorporated into an improved turbo drill of Dresser manufacture. □

A proposed multi-million-dollar acetylene plant will be located at Diamond Alkali's Deer Park Plant in Houston, Tex. Engineering studies are already underway, construction is expected to start in the fall of 1957. □

Ready to go on stream at Richmond, Cal., is California Spray-Chemical Corp.'s new multi-million-dollar plant-food plant capable of producing 300 tons of complex pelleted plant food, 300 tons of liquid ammonium nitrate, 150 tons of ammonium sulphate, 200 tons of liquid calcium-ammonium nitrate, and 400 tons of aqua ammonia per day. □

Construction is underway on a $3 million addition to American Synthetic Rubber Co.'s Louisville, Ky., manufacturing plant. Designed, engineered and constructed by the Southwest Division of Walter Kidde Constructors, Inc., the addition will increase synthetic rubber capacity by 50%. □



Hot rinsing plated parts at The Electric Auto-Lite Company, Woodstock, Illinois

How Auto-Lite's plating plant cuts waste-treatment costs in half!

Big chrome-plating plants have a tough waste-disposal problem. The chromic acid they use is toxic. When plating baths are exhausted and rinse water is contaminated, they have to be disposed of. In most localities, regulations prohibit the dumping of these toxic wastes in streams or sewers. And the chemical equipment for making these wastes non-toxic takes up a lot of valuable space and is costly to build and operate.

That's why the engineers at the Woodstock Plant of The Electric Auto-Lite Company looked carefully at all waste-treatment methods. They chose a Permutit ion exchange system that actually *recovers* the chromates for re-use!

Results: Plating baths last many times longer. Chromic acid consumption is cut about 65%. Total waste-disposal treatment costs are cut in half! And they get a cleaner, higher-grade plating job.

In the same way, ion exchange cuts costs in anodizing, bright dipping, pickling, brass etching, copper stripping. It also recovers copper and zinc from rayon wastes, concentrates uranium from complex ores, removes impurities from sugar, drugs, antibiotics.

We'll be glad to look into ways ion exchange might improve *your* process. The Permutit Company, Dept. CEP-11, 330 West 42nd St., New York 36, N. Y. or The Permutit Company of Canada, Ltd., Toronto 1, Ont.

PERMUTIT®

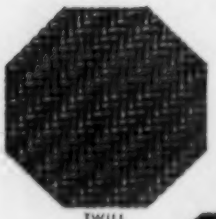
rhymes with "computo it"

ION EXCHANGE for Water Conditioning

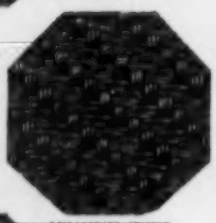
Chemical Processing • Industrial Waste Treatment

Newark Metallic Filter Cloth . . .

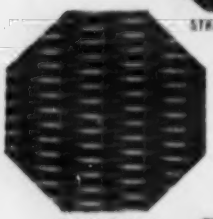
. . . says STOP to Solids



TWILL

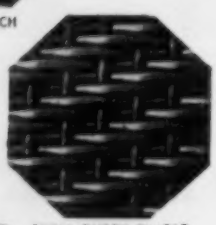


STRANDED TWILL

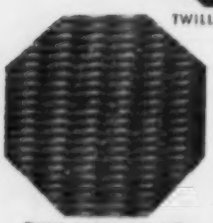


PLAIN DUTCH

Enlarged approximately 3X



TWILL DUTCH SINGLE



TWILL DUTCH DOUBLE

Newark Metallic Filter Cloth does stop solids — the wedge-shaped openings allow only the filtrate to pass through. And, Newark Cloth is reversible, both sides being identical. Newark Metallic Filter Cloth is woven firmly and uniformly without loose wires, guaranteeing good filtration all over.

Newark Metallic Filter Cloth is available in a variety of weaves in *all* malleable metals, and is adaptable to practically all types of filters. When writing, please give us details on your process.

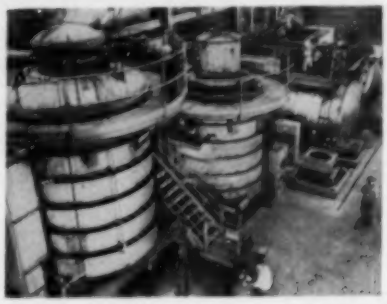
Send for our NEW Catalog E.

NEWARK for ACCURACY

Newark Wire Cloth COMPANY

351 VERONA AVENUE • NEWARK 4, NEW JERSEY

INDUSTRIAL NEWS



New vacuum methods are being studied in these horizontal and vertical vacuum furnaces at the new Vacuum Technology Building at Electro Metallurgical Co.'s Niagara Falls plant. The furnaces are designed to duplicate actual production conditions and offer any range of temperature and vacuum necessary in the field of metallurgy.

Archer - Daniels - Midland Co. has moved its Chemical Products Division headquarters to Minneapolis from Cleveland. □

A new Houston office has been opened by Badger Manufacturing Co. □

A new polyol production unit is now under construction at Celanese Corp.'s Chemcel plant in Bishop, Texas. Expected to be completed and producing by the last quarter of 1957, the new unit will utilize special aldoling processes developed by Celanese and will greatly expand capacity for polyol and aldol production. In addition to providing trimethylolpropane and other intermediates for polyurethane synthesis, the new unit will produce a range of other products. □

Multi-million-dollar expansion program at Diamond Alkali's Deer Park Plant near Houston, Texas, will increase Diamond's present daily production capacity of electrolytic products at Deer Park by approximately 40%, or 200 tons of chlorine, 220 tons of caustic soda, and 2 million cubic feet of hydrogen. □

The first completely "off-shore" sulfur mining operation in history is being undertaken by Freeport Sulphur Co. at a deposit six miles out in the Gulf of Mexico, under 45 feet of water. Discovered by Humble Oil during off-shore oil exploration, the deposit represents a "major new source" of sulfur. Freeport will mine the deposit, under the agreement between Freeport and Humble, after taxes and royalties to the Federal Government, each company will get about 50% of the net profits. Two other such domes are in the immediate area and are under study now

Land of CHEMICALS PLENTY*

the right place to locate your chemical plant

Natural and man-made elements combine in the Land of Plenty to create a formula for successful chemical plant location.

Excellent building sites in sizes especially suited to spread out chemical plants are available. They are near virtually unlimited supplies of the world's finest Bituminous Coal and pure limestone. Natural gas, petroleum, brines and other raw materials are plentiful, too.

In addition, with the chemical industry already well established here, there are numerous sources of basic raw materials for chemical processors.

The territory along the Norfolk and Western has many other advantages for the chemical industry. Why not let our plant location specialists tell you about them . . . in confidence and without obligation?

Abundant Mineral Resources

Adequate Power and Water

Home-Rooted Workers

Near Major U. S. Markets

Access to World Markets through the Modern Port of Norfolk on Hampton Roads

Moderate Year-Round Climate

Dependable N&W Transportation

Friendly Communities

Room to Grow

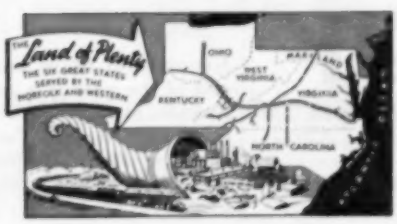
Favorable Industrial Tax Structures

Write, Wire or Call:

L. E. WARD, Jr., Manager
INDUSTRIAL AND AGRICULTURAL DEPT.
Drawer CP-731, (Phone 4-1451, Ext. 474)
Norfolk and Western Railway
ROANOKE, VIRGINIA

Transportation is a major factor in good plant location. YOUR TRAFFIC MANAGER is a transportation expert. Consult him about transportation advantages for your plant.

*



Norfolk and Western RAILWAY

HOW'S THIS FOR

MIXING CAPACITY?

Here's Modern Mulling for today's laboratory needs! LF Mix-Muller ¼ - ¾ cu. ft.

THIS IS THE 3F SIMPSON MIX-MULLER — with it, you can prepare 40 to 60 cu. ft. of *intimately* blended materials . . . in minutes. How many minutes depends upon what you're mixing, naturally. But, we have users who once counted materials preparation time in *days* . . who now talk in minutes, thanks to their Simpson Mix-Muller.

Mixing is our *business* at National; it has been since 1912. In recent years, increased mixing capacity for today's production requirements has been a *big* part of that business. That's why the Simpson Mix-Muller utilizes a stationary pan, automatic bottom discharge and is equipped with spring loaded mullers . . . to make the *most* of every minute of mixing cycle duration.

Available in 13 models in batch capacities of 1/10 to 60 cu. ft., Mix-Mullers are available to meet a variety of processing needs— as a reaction vessel, for heating or cooling while mixing . . . in stainless or other special materials of construction. Write for details.

Here's the Handbook on Mulling. Write for your copy today!

SIMPSON *MIX-MULLER*® DIVISION

NATIONAL ENGINEERING CO. (Not Inc.)
652 Machinery Hall Building
Chicago 6, Illinois

INDUSTRIAL NEWS

This portable warehouse is entirely supported by air and is large enough to hold two million pounds of packaged goods. Developed by United States Rubber Co. for Calumet Industrial District, Chicago, the pneumatically supported building is 80 feet long, 40 feet wide and 20 feet high. It contains 64,000 cubic feet of storage space, weighs about 400 pounds, and costs about $2,000. It is made of a paper-thin, extremely tough nylon fabric called Fiberthin, and is coated with vinyl plastic.

Plans are underway for a new fabricated carbon products plant of Union Carbide to be operated upon completion by the company's National Carbon Products Division. The new plant, to be located four miles south of Lawrenceburg, Tenn., will have an annual productive capacity of 12 million pounds of carbon products.

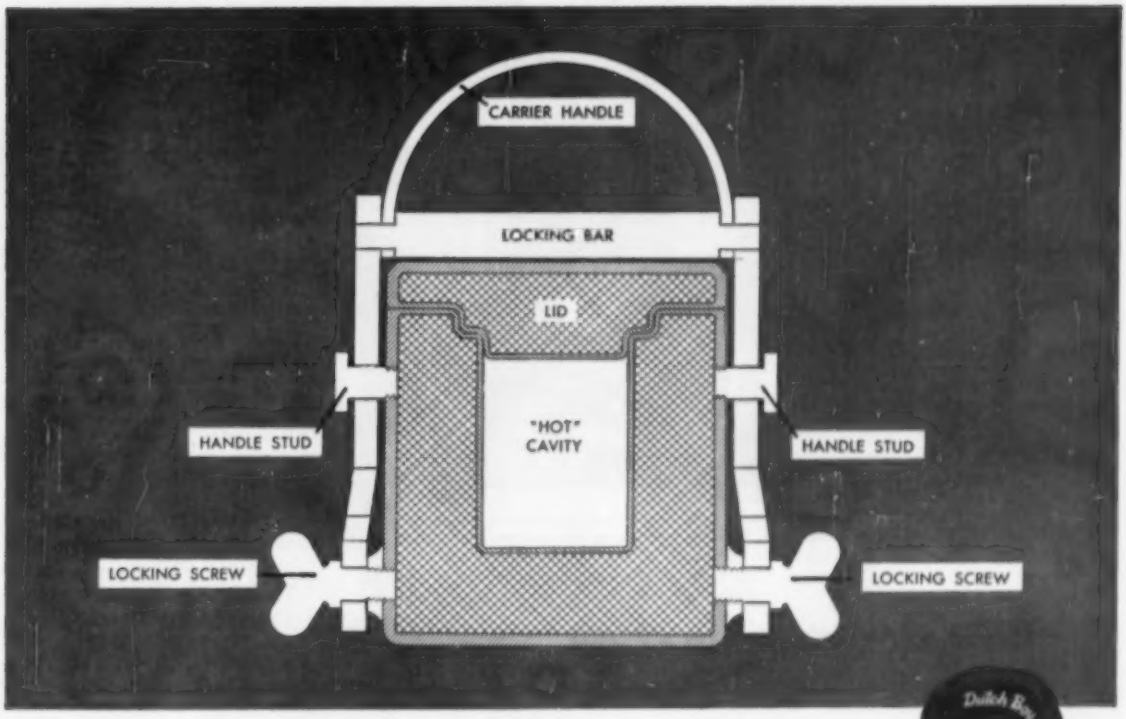
This increase in productive capacity is independent of National Carbon's 100 million pound per year increase in annual productive capacity of carbon and graphite electrode products. □

A new $1 million plant is being built by Wendnagel & Co., Chicago, 100-year-old manufacturers of wood tanks widely used in the chemical process industries, and fabricator and erector of structural steel. □

A multi-million-dollar expansion program which will increase annual production of butadiene by 50% is underway at the Port Neches, Tex., plant of Goodrich-Gulf Chemicals. Full production from the new facilities is scheduled for the fall of 1958. □

Erection of a $2 million refining facility for the Jones & Laughlin Steel Co. is now well underway. Prime contractor is Badger Manufacturing Co., and the facilities, located in Aliquippa, Pa., will incorporate for the first time in the steel industry the patented Hydrofining sulfur removal process. □

Expected to be in operation by the end of the year is a new oxygen and nitrogen plant of the Medical Gas Division of Thomas A. Edison, Inc. The plant, at North Grafton, N. J., will produce the gases for industrial as well as medical use. □



Now! From National Lead... new, small, containers for *"hot"* shipments

These new National Lead containers, currently produced in four sizes, simplify the shipping and handling of radioactive materials.

The containers are designed to meet ICC-55*** requirements for shipping Group I and II Class D poisons (radioactive materials emitting gamma rays and/or neutrons, alone or with electrically charged corpuscular rays).

Lead-in-steel provides the shielding. Lead thicknesses run from ½" to 2", depending on container size. The stainless steel jacketing keeps the lead where it's needed ... even if melted accidentally. The handle locking bar, side bars, studs and screws are heavy steel. The stepped closure prevents "beaming."

Easy to handle ... easy to decontaminate.

If you need shipping containers like this ... or any other type of lead shielding in any shape, size, or tonnage, call on National Lead.

Seals tight. "Lid-loc" handle secures closure against opening from impact, makes for easy handling. Offset closure prevents "beaming."

National Lead Shielding

NATIONAL LEAD COMPANY: New York 6; Atlanta; Baltimore 3; Depew (near Buffalo); Chicago 80; Cincinnati 3; Cleveland 13; Dallas 2; Philadelphia 25; Pittsburgh 12; St. Louis 1; Boston 6 (National Lead Co. of Mass.); Los Angeles 23 (Morris P. Kirk & Son, Inc.); Toronto, Canada (Canada Metal Co., Ltd.).

Program Control Panel used at Delaware Station, Philadelphia Electric Co. to automatically start and stop their W&T Slime Chlorination System.

HOW W&T CHLORINATION

controls slime in power generating plants

The Philadelphia Electric Co. has W&T chlorination equipment installed in their steam-electric generating stations to prevent slimes from fouling the turbine condensers and lowering the efficiency of the units. Maintaining cooling efficiency saves enough fuel to more than pay for the treatment.

Chlorination is controlled from a W&T Program Control Panel like the one pictured. Operators preselect chlorine dosage and treatment times. Chlorination is started and stopped automatically in accordance with the preselected schedule. The result is positive slime control without requiring personnel to supervise each treatment and without the expense of chlorinating continuously.

For information about W&T Slime Control Systems write for Bulletin CD-42.

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SEBACIC ACID

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H-25

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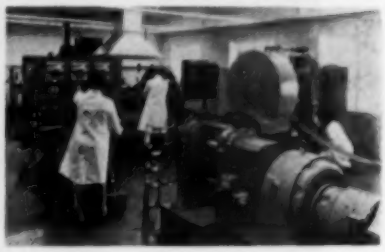
INDUSTRIAL NEWS



The new Polymer Laboratory of the Enjay Co. has doubled the size of the company's Linden, N. J., sales technical service facilities. Equipped with the newest and most advanced equipment in the field of rubber technology, most of the new laboratory's program will be devoted to applications-research work on Butyl, the synthetic rubber made from refinery gases.

The Odessa Butadiene Company has been authorized to install a Houdry dehydrogenation process unit to produce 50,000 tons per year of butadiene. The Fluor Corp. is in charge of construction, and the unit is to be completed by July, 1957, at a site near Odessa, Tex. It will be operated solely for butadiene production. □

A jointly-owned company, Mountaineer Carbon Co., has been formed to operate a carbon calcinating plant with a yearly output capacity of 165,000 tons. The plant, which is located near Cresap, W. Va., will produce and market high grade calcined carbon to be used principally as electrode carbon material in the chemical, aluminum and electro-metallurgical industries. Joint owners of Mountaineer are Pittsburgh Consolidation Coal Co. and The Standard Oil Co. (Ohio). □

A new nylon plant designed to produce 40 million pounds of fiber annually to meet the growing demand for its use in tire cord and other industrial products will be built by Du Pont in Richmond, Va. □

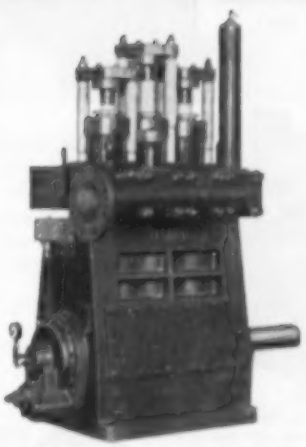
What is being called the first universal drilling mud dispersant to be produced with scientifically predictable field performance plus the long sought ingredient of price stability, is being produced in Canada by Alaska Pine & Cellulose, Ltd. Called Rayflo, the chemical is now in large tonnage production at a recently built multi-million-dollar plant in Vancouver, B. C. Expected to be a complete replacement for imported dispersants, such as South America's quebracho, Rayflo is the result of years of research by Rayonier, Inc., of New York. The new dispersant is a "silvichemical," i.e., a highly complex organic chemical produced from wood but not a cellulose product. □

"It'll pay us to replace it with an ALDRICH PUMP!"

Downtime, due to pump failure, is always a costly item. It takes the reliability and freedom from maintenance found in an Aldrich Pump to assure maximum dependability in overcoming the problems of corrosion, abrasion, high viscosity and high pressures. The tougher the job . . . the more important it becomes to take advantage of our wide experience in building pumps for the chemical industry.

On the less critical jobs, too . . . it makes sense to call Aldrich. The simplicity of the Aldrich Direct Flow design, with fluid-end sectionalization, offers substantial economies in both operation and maintenance. Fluid-end designs are available in aluminum bronze, stainless steel, Hastelloy and titanium.

A copy of our new condensed catalog showing the line of Aldrich Pumps, is yours for the asking. Write today for Data Sheet 100. The Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.

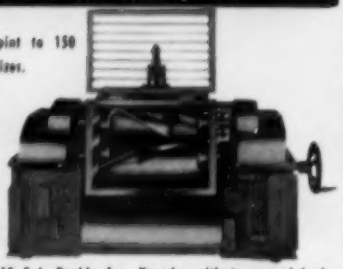


Aldrich Direct Flow Pumps are especially well suited to chemical service. The complete Aldrich line includes Triplex, Quintuplex, Septuplex and Nonuplex Pumps, 25 to 2400 hp.

THE ALDRICH PUMP COMPANY

Leading mfrs. of
MIXING AND
GRINDING EQUIPMENT
for over 90 years

• 1 pint to 150 gal. sizes.

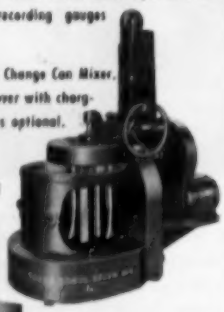


#41L–10 Gal. Double Arm Kneader with two speed brake motor. Jacketed trough and motor operated lift optional.

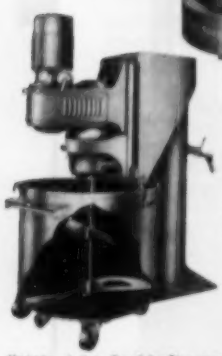
• 4½ x 10, 6 x 14, 9 x 24, 12 x 30, 14 x 32, 16 x 40" sizes.

#52TC–14" x 32" High Speed Three Roller Mill. Hydraulic adjustment and pressure recording gauges optional.

#30C–50 Gal. Heavy Duty Change Can Mixer. Adjustable outer scraper, cover with charging port, and gates on cans optional.



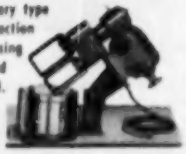
• 8, 16, 20, 50 and 40 gal. sizes.



#130H–250 Gal. Change Tank Mixer with hydraulic raising and lowering and variable speed motor. Various type stirrers and high speed impellers optional.

• 80, 150 and 250 gal. sizes.

#130EL–1 Gal. Double Planetary type Change Can Mixer with shearing action stirrers, and variable speed reversing type motor. Jacketed cans and portable trucks for cans optional.



• 1, 2, 3, 4, 6, 15, 25, 50, 65, 85, 110 and 150 gal. sizes.

Write for complete information on these or other types of ROSS equipment.

CHARLES ROSS & SON COMPANY, INC.

150 CLASSON AVENUE
BROOKLYN 5, NEW YORK

PEAT...

an important raw material?

Edgar L. Piret and R. G. White | University of Minnesota

The peat resources of the United States are enormous, with about half, or seven billion tons,* being located in Minnesota.

Many courageous efforts have been made to find uses for peat, for example for farming, for fuel and gas, for peat moss in agriculture and gardening, etc. In general, the success of these uses has been of limited scope. The high initial and equilibrium water contents of peat are well known to be important obstacles to some of its potential uses. The basic problem is one of *economics*.

Obviously one can get heat, reducing gases, and tars from peat. And it is well established in the literature that one can also get waxes, resins, celluloses, hemicelluloses, pentoses, humic acids, etc. But can these materials find economic outlets?

Economics

When considering uses for peat, it is necessary to keep in mind that what is economical in certain other countries may not be so in the United States. In Ireland, the lack of native coal makes the use of peat as a fuel much more attractive than in the United States. Finland and Sweden also are coal-poor countries. Hence, peat as a fuel can be of particular importance there, and because of this these countries have devoted much effort to the problem. In Minnesota, the cost of mining, the climatic conditions, the excessively high water content of peat as found in the bog, and its high equilibrium moisture content, combine with a basically low heating value to make it improbable that Minnesota peat can successfully compete in the United States with other fuels as a source of heat.

One must remember that steam coal in Duluth costs about $7.00 per ton, that is, about ⅓ of a cent per pound. Hence, peat as a potential fuel has in coal a serious competitor in Minnesota. Furthermore, we can expect to have natural gas as a competitor in the region before long. And when these fuels become scarce and expensive, then peat will have to contend with North Dakota lignite, which has a higher heating value. Probably by that time it will also have to compete with atomic energy as a source of energy and power. The day of peat as a fuel may, therefore, never come. In any event it seems basically wrong to burn a natural organic resource of this type. Peat should not be burned as a fuel but its future potential lies rather in its development as a source of chemical products.

For example, the so-called humic acids fraction of peat can be readily extracted with alkali. It represents a mixture of organic polybasic acids having an average molecular weight of about 1300. This material, while complex, is rich in functional groups, and participates in a wide variety of reactions. Furthermore, since this fraction constitutes up to 40% of the peat, we see that perhaps a billion tons of these acids lie in northern Minnesota. Compared with many organic acids, humic acids can potentially be made available at a very low price. Undoubtedly they will need study and development if they are to find profitable uses. Few product-minded investigations have been recorded to date.

Non-Fuel Developments Abroad

In this connection industrial groups and governmental agencies in several countries are studying and have studied peat extensively. The Province of Quebec is now carrying on a substantial and intensive study of the structure, composition, and profile of selected peat bogs in the Province, with the view of developing chemical rather than fuel applications. The Peat Research Laboratories of the State Institute of Technical Research of Finland is doing extensive work on the resins and waxes which can be solvent-extracted from peat. They find that whereas the mixture of bitumens extracted from peat is not particularly attractive to industry, if the mixture is fractionated to separate the resins from the waxes, each of these is useful in its own right.

The Société Carbochimique, an important and well-established Belgian chemical firm, is producing humic acids by the oxidation of coal in a ton per day pilot plant, and is evaluating derivatives of these acids in an extensive agricultural program. Related products should be obtainable from peat.

A large French fertilizer firm, Société Engrais d'Auby, has recently developed

(*Continued on page 96*)

* Air-dried basis, containing about 30% moisture.

Researchers:

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This new research tool has tremendous potential. The use of lithium metal as a catalyst for the polymerization of diolefins has been known for many years. By contrast, lithium metal dispersions were only recently used to polymerize isoprene to a "natural" rubber.

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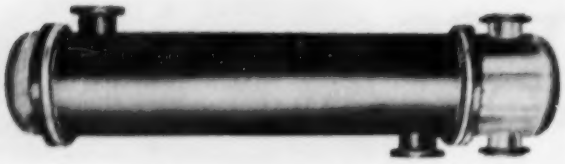

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PEAT . . . Raw Material?

(*Continued from page 94*)

an open-air peat fermentation process and in 1954 sold 160,000 metric tons of their peat product as a fertilizer. Five years ago they were starting off at only 1,000 tons of products per year. Eight years of intensive laboratory research were required to develop their process.

A Dutch chemical firm, which has a well known subsidiary in the U.S.A., has for years been producing, with careful chemical control, from peat deposits in the Netherlands, activated carbons of high quality for use in purifying sugar, water supplies, etc.

The Soviet Union has enormous peat deposits, a well-developed peat industry, schools at which peat technologists are trained, and several institutes devoted solely to peat research. However, technical information from Russia has been meager.

All the above activities are encouraging and point up the possibilities of developing chemical products from peat. But there are many questions to be answered. Are the above-mentioned foreign products competitive on the American market? Are our peat deposits of correct composition, etc.? And where, specifically, are the most desirable peat deposits located? For not all peats will be successful for such uses. For example, their chemical composition and geobotanical and physical characteristics vary widely, they will not ferment equally well, nor do all peats have sufficiently low ash contents to produce the quality of product needed.

All the bogs are not the same in composition and neither of course are the various strata in the same bog. For example, one stratum has 10% humic acid content, another 40% and so forth. Hence, a certain bog or stratum may be useful for purpose A but another bog or stratum may be best for purpose B. Today, the potential user is at a loss as to where to start.

Domestic Developments

Thus it is evident that we need basic information on the composition of peat and peat deposits; we need facts if we want to insure and accelerate the eventual uses of peat. As a step in the direction of a long-range program, a research project was initiated at the University of Minnesota in 1954 under sponsorship of the state's Iron Range Resources and Rehabilitation Commission. It is aimed at the development of basic knowledge on peat and its constituents, from the viewpoint of eventually developing chemical products from peat. The present attack is three-

(*Continued on page 98*)

7 years' trouble-free service on HCL acid with this Crane diaphragm valve

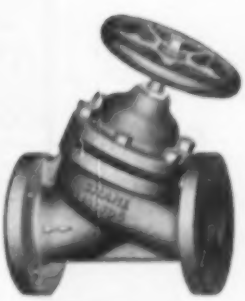
How do Crane diaphragm valves perform on acid services?

This major container manufacturer has impressive proof. Seven years ago, the Crane 4-inch No. 1615-RN rubber-lined diaphragm valve shown above was installed on 17 deg. Baume hydrochloric acid service. The acid is used to clean evaporators and surface condensers. *Not once has this Crane diaphragm valve failed to function—not once has it failed to hold tight.*

Previously, this plant used conventional all-metal valves. These had to be replaced regularly as an expendable material. The Crane valve has eliminated all replacement costs by providing maintenance-free performance—and from all appearances will continue to do so for years to come.

You just don't get service like this from ordinary valves. Crane valves are so expertly designed, have such quality materials and are so carefully machined and tested that cost-free records like this are the rule rather than the exception with Crane users.

Get the facts on Crane diaphragm valves from your local Crane Representative, or write to address below.



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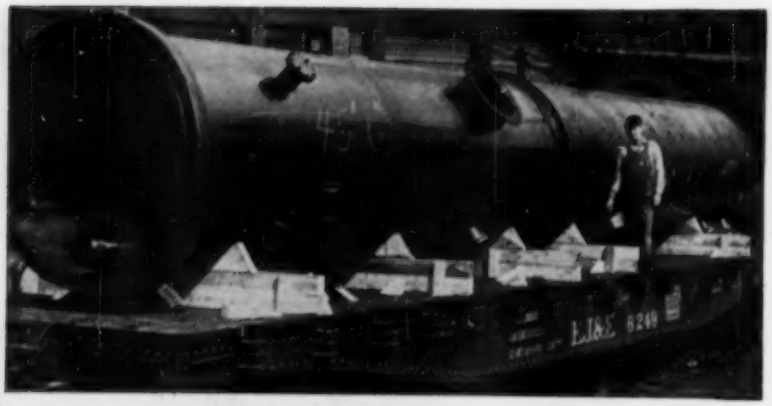

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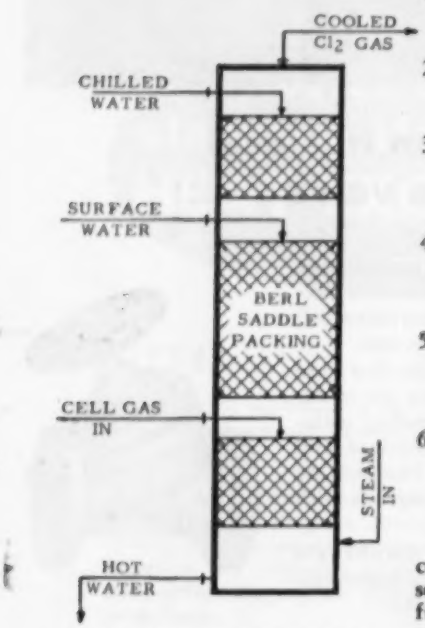

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Acid and Alkali-proof Chemical Equipment

PEAT . . . Raw Material?

(*Continued from page 96*)

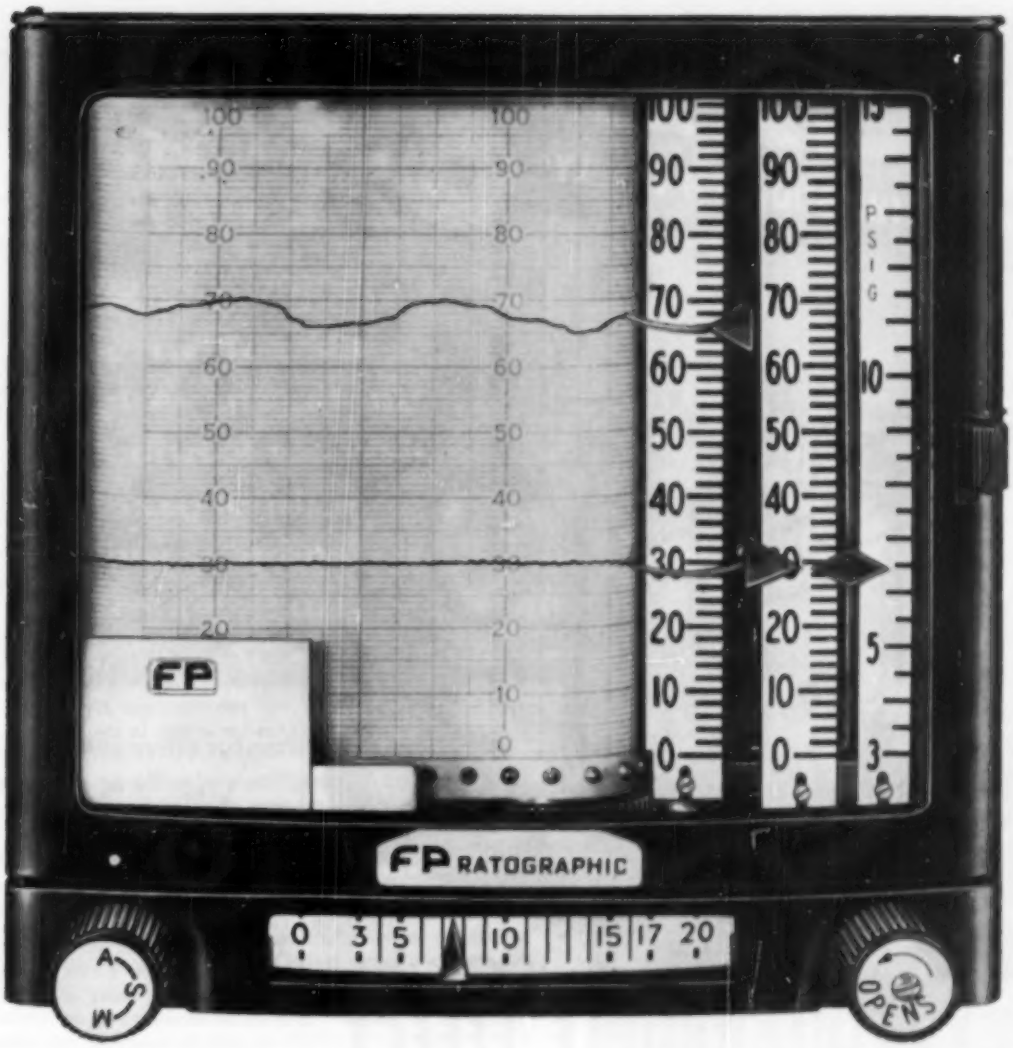
pronged. The program utilizes the cooperation of three University of Minnesota groups. The Chemistry Department, Duluth Branch, is cooperating with the Chemical Engineering Department, Minneapolis Campus, and also with the Soils Department, Agricultural Campus. Some results have already come from the program.

1) **A comprehensive library of the world's literature on peat has been established in the form of a modern punched card system, having some 8,000 abstracts to date.**
2) **A comprehensive method for the chemical group analysis of the components of peat is being developed and applied.**
3) **A series of nitrogen-bearing chemical derivatives of the humic acids extracted from peat have been prepared by organic laboratory procedures and are being evaluated in the Soils Department and also by the N. E. Agricultural Experiment Station for potential agricultural applications. It is because of the reported success in agriculture of peat products developed in Europe that the present development phases of the research program are largely pointed towards the application of Minnesota peat as a fertilizer product. This does not exclude, however, the interest in the potential of other chemical possibilities for peat.**
4) **Alkaline humic acids and peat mixtures have been found to be effective binders for the pelletizing of taconite fines.**
5) **A program of sampling and of chemical analysis of a number of selected peat bogs in Minnesota is in progress. This program will not only give the average composition of a bog, but also will give information on the composition of the various strata. Peat classifications are being developed.**

The above then are the first elements of a program which we believe and hope will provide needed and useful basic information, and which will lay foundations for a successful development of the peat resources of Minnesota. Progress will be slow but we believe the program to be pointed in the right direction.

The completion of a $2 million building and expansion program at Alco Products' Beaumont, Tex., plant will substantially boost production of the company's heat exchangers and oil field equipment. □

A patent has been issued on a basic process for manufacturing flexible and rigid polyurethane foams and rubbers. The invention covered by the patent, which is controlled in this country by Mobay Chemical, provides an injection technique used in the manufacture of urethane products which permits closer quality control of the process as basic chemical ingredients are blended and mixed under pressure. The technology involved is currently being employed by a group of major American firms under license from Mobay. □



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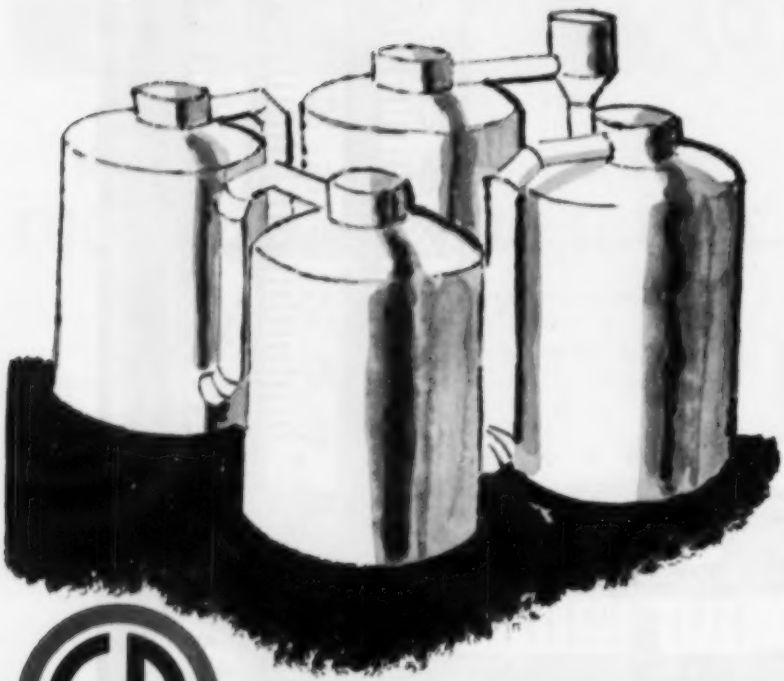

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OVERSEAS NEWS

Portugal's Junta de Energia Nuclear, that country's counterpart of AEC, has bought a 2 million volt Van de Graaff particle accelerator from High Voltage Engineering Corp., Cambridge, Mass. To be used in research, and in the training of nuclear physicists and engineers, the machine, first U. S. built particle accelerator to be shipped to Portugal, will be installed and operated in a new facility being built in a Lisbon suburb. Principal programs to be carried out with the accelerator will be in nuclear physics, radiation chemistry, and engineering. □

A $10 million Acrilan acrylic fiber plant will be built in Northern Ireland for Chemstrand Ltd., wholly-owned British subsidiary of Chemstrand Corp. Construction contract has gone to Costain John Brown Ltd., preliminary site development and engineering work is already underway, completion is expected early in 1959. The new plant will produce some 10 million pounds of Acrilan a year in the first stage. □

Ethylene oxide by the direct oxidation of ethylene will be produced at the rate of 26 million pounds per year in a new plant to be engineered and designed by Scientific Design Co., Inc., New York, and built at Leverkusen, Germany, by Farbenfabriken Bayer. The new plant will operate under license on SD's direct air-oxidation process adapted to the local needs and conditions of Bayer.

Under the contract, SD will perform all engineering in the U. S. according to German specifications and standards, including electrical, mechanical, civil, structural, and piping in addition to the usual chemical engineering involved in adapting the process to Bayer's needs. With complete process responsibility, SD will send a team from the United States to put the plant on stream and supervise initial operations. The new Bayer plant will be the eighth ethylene oxide plant designed and engineered by SD. □

A design and consulting contract to assist in the development of a 300 ton per month titanium dioxide plant in Japan has been awarded to Brown, Blauvelt and Leonard of New York.

To be built for Nisso Steel Mfg. Co., Tokyo, the new plant will be located in the northern part of Japan, adjacent to Nisso's newest plant which produces pig iron and by-product high titanium content slag from native iron-titanium beach sands. □

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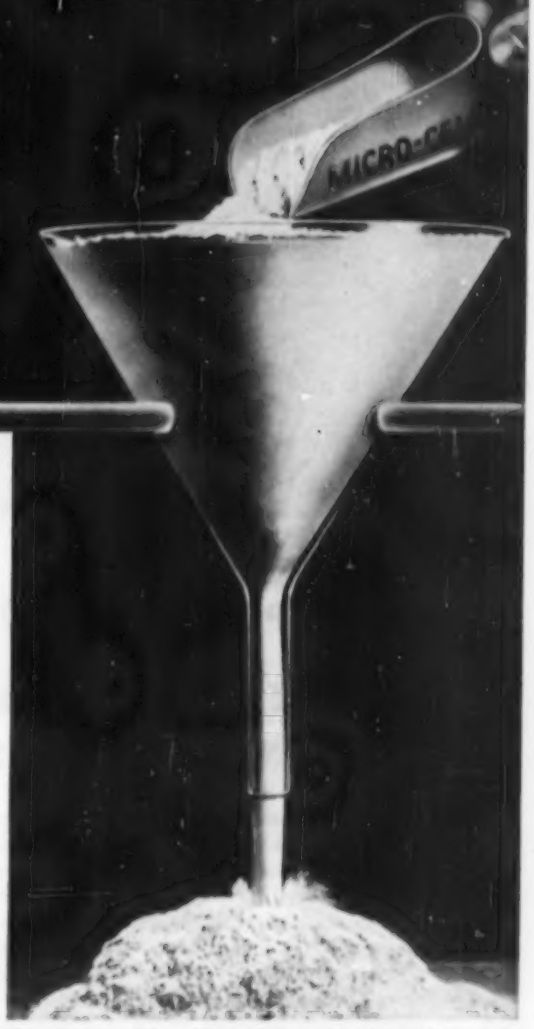

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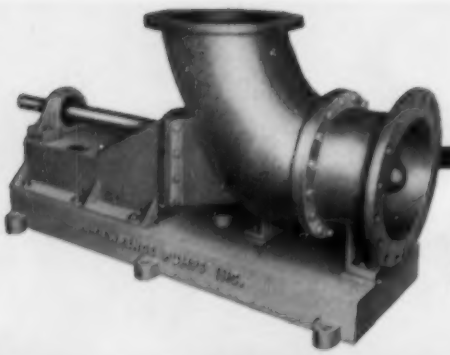
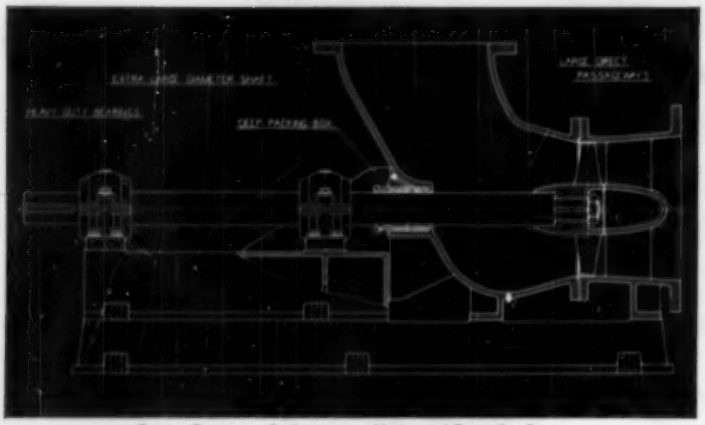


Lawrence 24" Horizontal Circulating Pump of Nickel Alloy Construction



Cross Section of Lawrence Horizontal Propeller Pump

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OVERSEAS NEWS

A 3,000 bbls./day Houdriforming unit for high-octane gasoline production is being built by Daikyo Oil Company, Ltd., of Tokyo at its Yokkaichi refinery. Scheduled for completion in the summer of 1957, the unit will be the first of its type in the Orient. Here, Takeo Otsubo, Daikyo's managing director, negotiates with C. C. Peavy and C. G. Kirkbride (standing) of Houdry Process Co. which will do part of the engineering. Refinery Engineering Co. of Tulsa will also work on the project, and Daikyo will handle construction.

Air Products, Inc., Allentown, Pa., has been awarded a contract by the Government of Venezuela for the design and fabrication of an air separation plant and a hydrogen purification plant. This is, according to Air Products, the first petrochemical operation of its type in South America.

The two plants, to cost over $1 million and to be installed some time next year, will be used to produce ammonia synthesis gas. The plants will be capable of producing 120 tons of ammonia per day. □

The U. S. Government will contribute $350,000 toward the cost of a nuclear research reactor project of the Danish Atomic Energy Commission. Foster-Wheeler Corp. will design and construct the mechanical components of the reactor. Initial cost of the reactor and its associated facilities is estimated at about $1,400,000. □

Hercules Powder Co. is entering the wood naval stores industry in Mexico for the recovery and utilization of pine stumps. Entry was made through the acquisition of stock in Corbu Industrial, S.A. A new plant will be built near Ciudad Hidalgo, Michoacan, and will manufacture 25 million pounds of wood naval stores products a year. □

A 25 million pound per year polyethylene plant using Phillips Petroleum's new catalytic process for making polyethylene and other polyolefin plastics will be constructed at Grangemouth, Scotland, by British Hydrocarbon Chemicals Limited, a jointly owned company of The Distillers Company Limited and British Petroleum Company Limited. □

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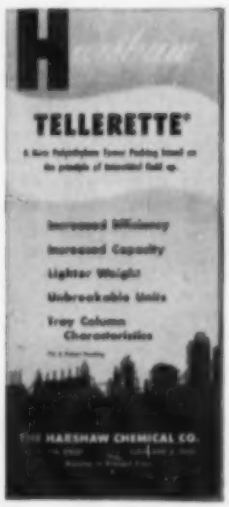

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WESTERN HEMISPHERE ENGINEERS MEET IN MEXICO

The Union Panamericana de Asociaciones de Ingenieros (UPADI) met October 8 to 12 in Mexico City. Some 200 engineers from 16 countries, including a large contingent from the United States, were present.

At formal opening on October 8, Don Adolfo Ruiz Cortines, President of Mexico (in glasses, center), and UPADI convention officers hear James M. Todd, chairman of EJC delegation, address the convention.

Passing over 30 resolutions, holding two important roundtables—one on atomic energy and the other on engineering education—UPADI showed at this meeting its growing vigor as a working, international, Panamerican engineering organization. Host was la Union Mexicana de Asociaciones de Ingenieros, whose president, Miguel Alberto Mantilla, was president of the meeting.

Most important resolution, perhaps was one introduced by Walter Lobo of the A.I.Ch.E. It said, in brief,

"It is recommended that the Board of Directors (of UPADI) appoint a committee comprised of 7 representatives of UPADI members, two from North America, two from Central America, one from the Caribbean area, and two from South America.

The purpose of this committee will be to suggest new plans and methods to the Board of Directors in order to achieve the objectives of the Union. These suggestions will be classified in order of their importance, and the expenses involved, in three categories:

a—Those suggestions that may be carried out without cost.

b—Those suggestions that may be carried out at a low cost to UPADI.

c—Those suggestions that require a high cost in relation to current economic resources but which may be taken into consideration.

The suggestion committee will send a copy of the proposals to the Board of Directors and to each of the members of UPADI."

In essence, this resolution is a concrete measure to give UPADI effective working "teeth," to give it a stronger continuity, and to create a real Pan-American engineering organization for the benefit of the entire hemisphere.

Other resolutions urged that formal sessions on engineering education be held simultaneously with future conventions of UPADI, that scholarships be made available to engineers for study in other countries, that technical institutes be established for technicians and foremen. The compilation of a dictionary of common engineering terms was suggested, as was close cooperation with the Panamerican Committee on Technical Standards. Lastly, engineers were asked to study means of increasing productivity and participating in productivity centers wherever they exist.

Round Tables—Atom and Education

Main highlights of the meeting were two roundtables which attracted many delegates.

At the session on atomic energy, C. Goodman, United States AEC, reaffirmed the U. S. policy of sharing its knowledge of the peaceful applications of atomic energy with the Latin Ameri-

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can nations. The U. S. is assisting in the manufacture of nuclear reactors and is making research facilities available to Latin American scientists. The Convention urged the Western Hemisphere nations to draw up uniform legislation on atomic energy, and provide for complete exchange of information on raw materials availability and resources. It asked for a report at the next convention on progress in the search for mineral deposits, production figures, and the uses of radioactive isotopes in agriculture, industry, biology and medicine.

The roundtable on engineering education was also conducted by a U. S. representative, L. H. Johnson, Dean of the School of Engineering, Tulane, and featured the remarks of Ralph Morgan, Purdue Research Foundation. The engineers at this session developed five general areas of agreement on which to base future activity.

1—There is a great need in engineering schools for full time professors at attractive salaries.

2—The development of engineering education is the joint responsibility of industry and government.

3—There is need for a study of basic requirements in engineering curricula and facilities.

4—The next UPADI Convention should include a program for engineering educators.

5—A permanent UPADI Committee on Engineering Education should be formed to function between conventions.

The first synthetic rubber plant in Great Britain will be built by Blaw-Knox' Chemical Plants Division for an industrial group headed by Dunlop Rubber Co. To cost $12 million, the plant will have a capacity of 50,000 long tons of GR-S synthetic rubber per year. Name of the new group, which includes Goodyear Tyre & Rubber, Firestone Tyre & Rubber, and Michelin Tyre Co., is International Synthetic Rubber Co. □

The Glidden Co. and W. R. Grace & Co. have jointly invested $1 million in the manufacture and distribution of quality paints in Colombia. □

The U. S. Government will contribute $350,000 toward the cost of a nuclear research reactor project to be undertaken by the Netherlands Centre. American Car and Foundry Industries, Inc., has been selected to design, engineer and construct the reactor. The buildings will be designed and constructed by a Netherlands firm. Cost of the reactor is estimated at $2 million, cost of the entire project may run to $3 million.

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ETHICAL PROBLEMS . . . and the engineer

With "unionism" making strong efforts to challenge the concept of the professional engineer, the problem of professional ethics grows in importance each day. At its October 26 annual meeting in Detroit, the Engineers' Council For Professional Development grappled with the subject in a direct, highly pertinent open discussion meeting of its Committee on Ethics, led by C. J. Freund, Univ. of Detroit. A digest of the problems and the results of the discussion is presented here by CEP.

Compensation—New Men vs. Old

A consulting engineer has in his employ a trusted and competent engineer to whom he pays $9,500 per year. This engineer likes his connection and his work, has had fourteen years' experience, has his home established in the community. As far as the employer knows, he is quite satisfied to remain at $9,500.

The employer wishes to add a June college graduate to his staff and finds that he must pay the June graduate $430 per month. He needs the college graduate very badly but $430 is by far too much in comparison with the older engineer's salary of $9,500.

How should the employer proceed?

Discussion Leader: L. F. Grant
Engineering Institute of Canada

This problem seems to belong somewhere between management and engineering practice.

It must be assumed in this discussion that the employer in question can afford to raise the salary of the older employee.

Through it all, it should be remembered that engineers must be treated somewhat differently than employees on an hourly basis. Much has been said about labor unions in engineering, but there is little indication that engineers are joining unions in any significant numbers. Very few engineers wish to be classified with labor.

In all these questions a special characteristic of professional engineers stands out. To the professional engineer his job is sacred. This refers to the responsibilities pertaining to his task, and is something quite different from company loyalty. In a sense, the professional engineer is even more devoted to his particular project than he is to his employer or client.

The consensus seemed to be that the pay of the older engineer should be increased in order to maintain an appropriate relation to the pay of the young graduate.

Know-How vs. Confidence

An engineer has been employed nine years by a corporation and is quite familiar with an improved plating process which his employer has developed. In fact, the engineer has had a principal part in the development of the process. This process is considered confidential by the employer, although it is not patented or protected in any form.

The engineer and his employer have had a misunderstanding and the engineer has resigned to join a competitor of his former employer. To what degree may the engineer use in his new job the knowledge he has developed and acquired in the former association?

Discussion Leader: J. J. Uicker
University of Detroit

The engineer must recognize his responsibility to society. He must develop information in order to benefit humanity. On the other hand, he is not entitled to disclose information which his former employer considered confidential merely to give the new employer a financial or competitive advantage.

As an engineer becomes older, he acquires considerable information. Usually this is called experience. Much of it may be acquired from former employers or clients. Obviously the engineer cannot throughout his career suppress what may be the important elements in his experience.

New officers of E.C.P.D. elected at the October 26 meeting are: Morris D. Hooven, president; R. G. Warner, vice-president; E. D. Kirkendall, secretary; T. Marshall, assistant secretary; and S. L. Tyler, executive secretary.

E.C.P.D. Council also voted approval of the Joint Committee Report on a Survey of the Engineering Profession. A.I.E.E., A.I.M.E., and A.S.C.E. have voted to support this study up to the amount of $10,000 each.

On the other hand, his former employer should be entitled to protection of his confidential information for a reasonable period of time.

The employer should always compensate his engineers sufficiently to retain them in his employ if the engineers have confidential information.

Publication—When?

A research engineer is employed by an important steel processing corporation. He has completed experiments which have resulted in new and valuable information concerning the performance of certain steel alloys under vibration at extremely high temperatures. He proposes to report his researches and results in a paper.

The engineering vice president of the corporation objects. He says, "The results you get are for our use, not for every Tom, Dick and Harry in the United States who comes to an engineering meeting."

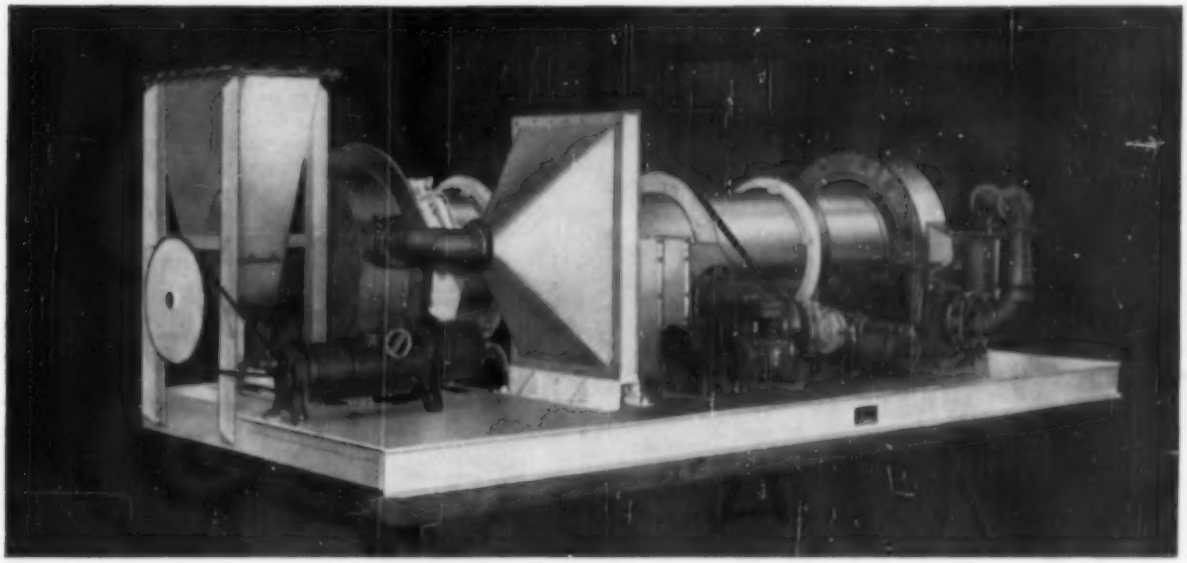
What can the research engineer do?

Discussion Leader: S. L. Stolte
Bettenburg, Townsend, and Stolte

The discussion makes it clear that the solution of this problem rests on proper timing. It is a real difficulty because it involves conflict between two of the ECPD Canons of Ethics. One says the engineer will co-operate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers, and the other says he will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

As in the case of the preceding problem, any employer or client can properly expect that his confidential information will not be disclosed. On the other hand, it is unreasonable of the employer to demand this kind of protection year after year. Accordingly, it

(*Continued on page* 108)



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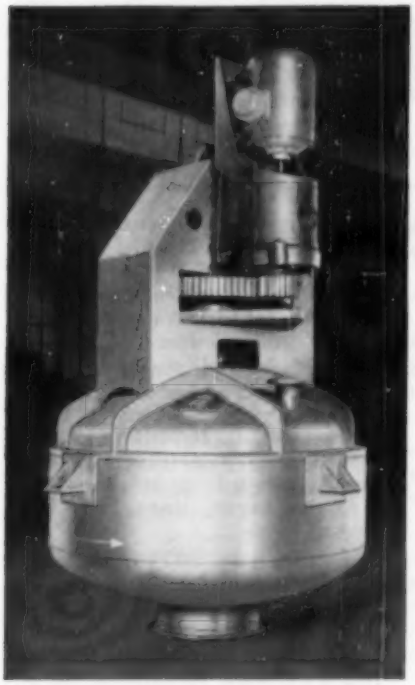

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ETHICAL PROBLEMS

(*Continued from page 106*)

appears that the engineer should be permitted to publish research results after the employer has had a fair opportunity to take advantage of them in a commercial way. In many cases the information may be secured by patents if the employer will bother to apply for them. Just where to draw the line in the matter of timing is a matter of ethical judgment. In any case, an engineer with a highly developed sense of ethical discretion will hardly go wrong in a situation like this.

Job Acceptance

A senior engineering student has been interviewed by prospective employers A, B, and C, and has informed A of his acceptance of his offer.

Is it ethical for the student:

1. **To reconsider his decision and investigate prospective employer N's offer which, incidentally, includes a check for $500 to compensate him for time and expenses during his investigation of N's offer?**
2. **To accept N's offer and renounce his acceptance of A's offer?**
3. **To retain the $500 check if he accepts N's offer?**
4. **To offer A no payment to alleviate any loss which A may have suffered by cancellation of the agreement?**

Discussion Leader: J. H. Foote
Commonwealth Associates, Inc.

Possibly this ethical problem concerns recruiters and prospective employers as much as it does students.

Fundamentally, any man who does not recognize a contract is dangerous to the community.

Students should be given lectures or other instruction in the matter of the legal aspects of professional practice. It should be pointed out to them that a contract, a meeting of minds, is a valid agreement whether written or otherwise.

Certainly it is not ethical for the student to consider another offer after he has agreed to join an employer unless he has obtained the permission of the first party. With such permission, consideration of the new offer is altogether proper.

In this connection, employers should be concerned about the competence and background of interviewers. The interviewer should understand and subscribe to codes of ethics. Educators, on the other hand, should take sharp issue with unethical recruiters, and possibly even deny them admission to the campus.

It appears to be time to republish and re-emphasize the "Ethics of Interviewing Procedures" of the American Society for Engineering Education. The Midwest College Placement Association has prepared a revision of this interviewing code.

The revised code should certainly be printed and circulated by ECPD, and should be widely distributed through all other appropriate channels.

NATIONAL CONFERENCE ON HEAT TRANSFER TO BE HELD

Sponsored by A.I.Ch.E. and the Heat Transfer Division of A.S.M.E., a National Conference on Heat Transfer will be held August 11-14, 1957, at Penn State University.

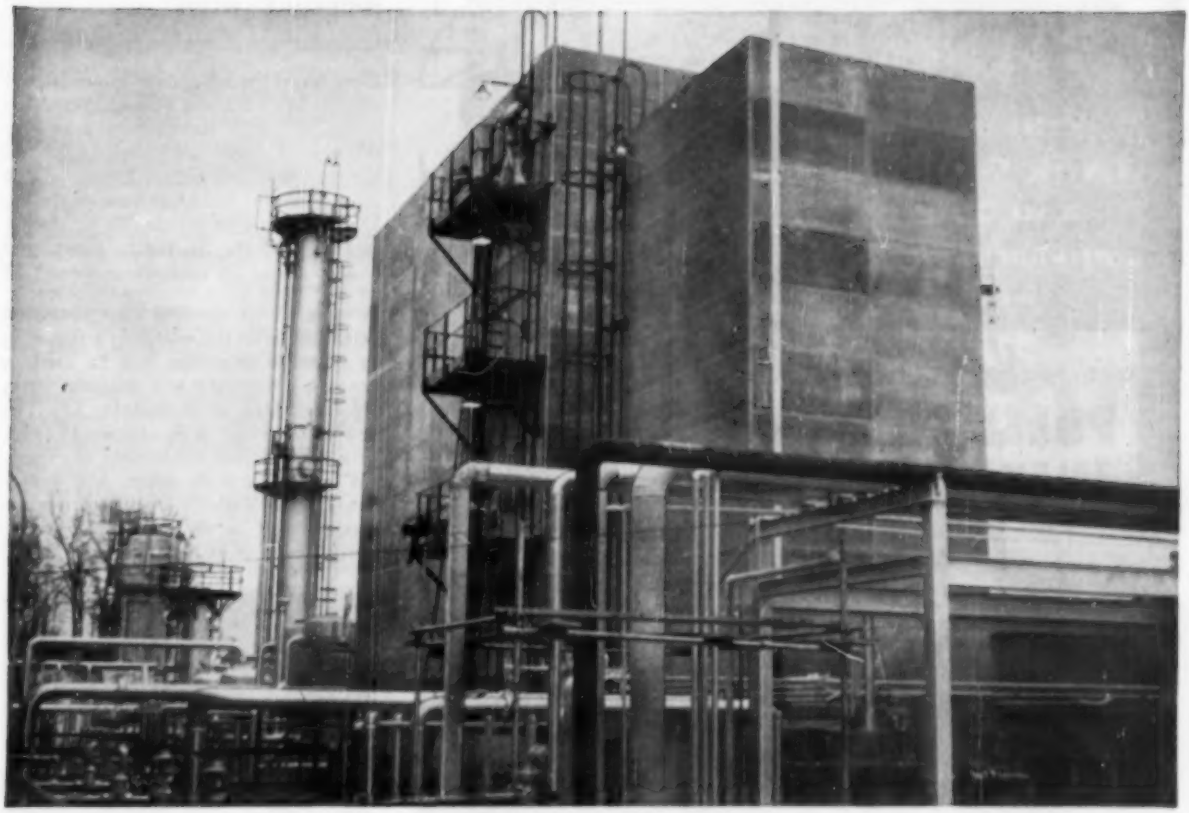
Theme of conference will be Applied Heat Transfer. Papers are being solicited which bear directly on Heat Transfer applications.

Expected to be an outstanding event in the field of heat transfer, the jointly sponsored conference will include, in addition to a first-rate technical program, an exhibit of equipment and apparatus used in industrial heat transfer. Manufacturers of equipment for the measurement, recording, control, and production of heat transfer and thermal processes are invited to show their equipment.

On the technical program, A.I.Ch.E. expects to be well represented. Particularly sought are papers dealing with the design, construction, and use of heat exchangers, economic and practical problems associated with insulation, methods of instrumentation and tests, and the results of research which may be applied in industrial practice. Chemical engineers wishing to present papers at the conference are advised to contact J. N. Addoms, Atlas Powder Co., Wilmington 2, Del., before December 1, 1956.

A special feature of the conference will be a dinner and ceremonies honoring Prof. William H. McAdams of MIT upon the occasion of his retirement from teaching. A special effort is being made to invite former students of Prof. McAdams.

The National Society of Professional Engineers has asked the U. S. District Court for the District of Columbia to rule that the National Labor Relations Board exceeded its authority in permitting nonprofessional employees to vote with professional employees in the determination of collective bargaining representation questions. In a "friend of the court" brief, the society said that NLRB's interpretation of the Taft-Hartley Act to the effect that a minority of nonprofessional employees may be included in a voting unit with professionals was in direct violation of the professional provisions of the labor law.



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INDUSTRIAL NEWS

Dow has formed a new international section of its Plastic Technical Service group to supply technical assistance in the use of Dow plastic materials sold abroad. The international section will also provide technical assistance to Dow's associated companies producing plastic products in India, Japan and Wales. □

A number of process improvements resulting from the company's research in metallic chlorides will be used in Stauffer Chemical's new titanium tetrachloride plant at Ashtabula, O. The new plant, which is in addition to titanium tetrachloride expansions at Stauffer's Niagara Falls plant, will supply the needs of National Distillers' titanium sponge plant in the same area, is expected to go on-stream late in 1957. □

This new, unique ship loader, designed for Freeport Sulphur Co.'s Port Sulphur, La., docks by Hewitt-Robbins, is designed to cut ship and barge loading time by one-half. Costing $1 million, the new travelling loader moves a distance of 400 feet along the dock and its discharge chute can extend 45 feet over the river and clear an elevation up 54 feet. It is operated by a small remote control panel in the hands of a single operator on the dock or on the bridge of a ship.

The contract to engineer and construct a detergent alkylate plant for Imperial Oil, Ltd., at Sarnia, Ontario, Can., has been awarded to the Fluor Corp. of Canada, a subsidiary of Fluor Corp. The plant, first of its kind in Canada, is Imperial's first step into the petrochemical field. Completion of the $3.8 million project, scheduled for next summer, will make Canada self-sufficient in detergent alkylate (dodecyl benzene). Oil refinery gases will be used in the operation which will have a rated capacity of 30 million pounds of detergent alkylate and smaller quantities of other alkyl aromatic compounds. Tripropylene and tetrapropylene will also be produced. □

Shipments from National Potash Co.'s new mine near Carlsbad, N. M., are due to begin in February, 1957. The $19 million project will have an annual capacity of 400,000 tons of high grade muriate of potash guaranteed 60% K_2O.

This 175,000 sq.ft. building will house both the new zirconium plant of U. S. Industrial Chemicals, and the just announced 10 million pound/yr. titantium sponge plant the company expects to have on-stream by the end of 1957. This new titanium plant will mark the first entry of a company into the titanium field without a Government procurement guarantee.

Columbium and tantalum oxides and metals up to 99.5% purity are now available from Kennametal, Inc., Latrobe, Pa.

Columbium (also known as niobium), when in a metal state of high purity is said to offer highly desirable characteristics that are needed in the atomic energy and chemical processing fields. High-purity tantalum is finding widespread use in several fields, particularly in the making of electronic components.

In addition to the high-purity grade columbium, a technical grade of the oxide and the metal is available for industrial research work and commercial purposes. □

New facilities for the production of methyl bromide at the Kolker Chemical Corp. plant at Newark, N. J., will allow Kolker to double its present methyl bromide capacity. □

Westinghouse Research Laboratories has announced plans to add a new nuclear research reactor to its scientific facilities. It will be the first such reactor to be built by an industrial firm solely for its own research use.

In the past 13 years some 40 research reactors have been built and many more are now under active consideration. The first such reactor built by non-governmental agencies began operation at North Carolina State College in 1953.

First lecturer in the E. P. Schoch Lecture Series at the University of Texas was W. K. Lewis, (right), MIT. Lewis praised Dr. Schoch (left) as one of the founders of chemical engineering and father of the chemical and petroleum industries in the South. The lecture series, established by ex-students of Dr. Schoch, who taught 60 years at Texas before retiring in 1954, was initiated on October 16, Dr. Schoch's 85th birthday.

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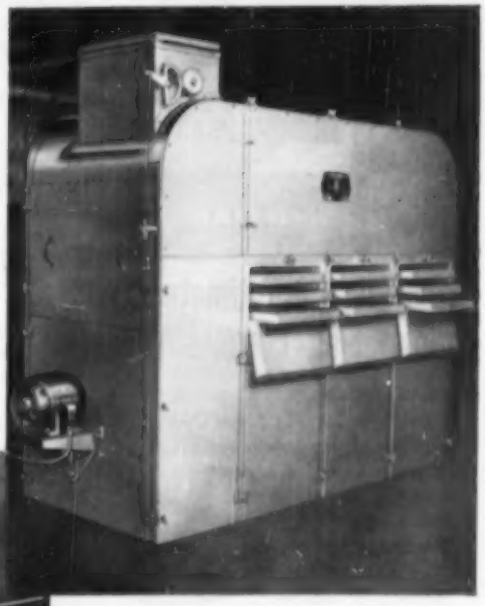

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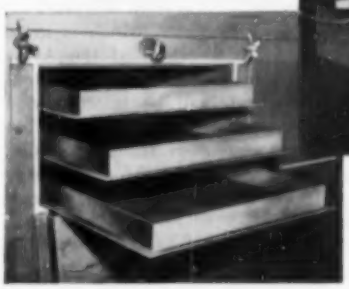

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NUCLEAR NEWS

The Atomic Energy Commission has received eleven proposals from industrial firms to participate in the design, development, and construction of a food irradiation reactor (FIR) for the U. S. Army Ionizing Radiation Center. The proposals which are now being evaluated were submitted in response to a general invitation issued by the Commission in July, 1956, to qualified engineering and manufacturing concerns.

The firms that made proposals are: ACF Industries, Inc., Washington, D. C.; AMF Atomics, Inc., New York, New York; Atomics International, Conoga Park, California; Bell Aircraft Corporation, Buffalo, New York; Blaw-Knox Company, Pittsburgh, Pennsylvania; Burns and Roe, Inc., New York, New York; Ebasco Engineering Company, New York, New York; H. K. Ferguson Company, Cleveland, Ohio; Goodyear Tire and Rubber Company, Akron, Ohio; Kaiser Engineers, Oakland, California; Rust Engineering Company, Pittsburgh, Pennsylvania.

The reactor will provide an intense source of gamma radiation for use in the food irradiation and preservation program of the Quartermaster Corps and in experiments with other materials. It will be water-moderated and will be fueled with solid fuel elements. A preliminary design concept is being completed for the Commission by Internuclear Company of Clayton, Missouri.

A site for the center, which is to be operated under direction of the Army Quartermaster Research and Development Command, will be selected soon by the Department of the Army on the basis of recommendations of a joint Department of Defense-Atomic Energy Commission site selection review committee. □

A co-operative educational program to provide advanced training in nuclear science and engineering for the staff at the Knolls Atomic Power Laboratory (KAPL), operated by the General Electric Company for the Atomic Energy Commission (AEC), is now in operation.

A group of nuclear engineering courses, carefully adapted to aid scientists and engineers working at the laboratory, forms one part of the program. Another group of courses is designed to offer a minor in nuclear engineering to scientists and engineers working on master's degrees in fields such as physics, mechanical engineering and metallurgy. These courses will stress the contributions of the varied fields in the broad development of nuclear science. □

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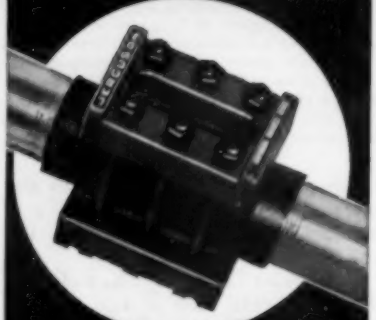

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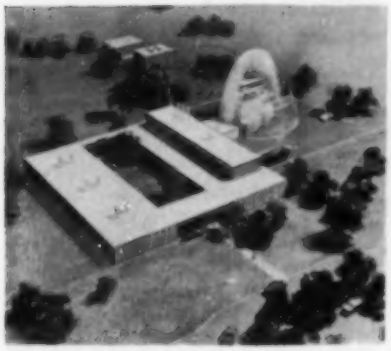

Ten of America's large corporations have formed a new company, Industrial Reactor Laboratories, Inc., to build and operate a privately owned nuclear reactor for industrial research in atomic energy, at Plainsboro, N. J.

The companies participating are Atlas Powder Co., AMF Atomics Inc. (Subsidiary American Machine & Foundry Co.), American Tobacco Co., Continental Can Co., Corning Glass Works, National Distillers Products Corp., National Lead Co., Radio Corporation of America, Socony Mobil Oil Co., and United States Rubber Co. Each participant is represented on the new company's board of directors, which will be headed by General Walter Bedell Smith, President, and H. L. Hilyard, Vice President. General Smith is Chairman and President of AMF Atomic Inc. Mr. Hilyard is Treasurer of the American Tobacco Co.

The AEC has authorized the negotiation of contract provisions for initial design and development work related to the nuclear power plant project proposed by the City of Piqua, Ohio, under the Power Demonstration Reactor Program. The Piqua proposal is for a reactor plant of 12,500 electrical kilowatts capacity, using circulating organic fluid (the hydrocarbon terphenyl) as moderator and coolant, and slightly enriched uranium as fuel. The plant would be located at Piqua.

The Commission has authorized modification and extension of its contract with North American Aviation, Inc., under which the company is designing, developing, and constructing an organic-moderated reactor experiment to be operated at the National Reactor Testing Station, near Idaho Falls, Idaho. The contract extension will be for development of reactor components, including a fuel element, for the Piqua project and other pre-construction research and development work. □

A new company to provide engineering and other services in connection with the design, construction and operation of nuclear reactors and other atomic energy facilities, and to carry out research and development work in the same area, has been formed under the name of the General Nuclear Engineering Corp. The new company is located in the St. Petersburg-Tampa area of Florida, is headed by W. H. Zinn, former director of Argonne National Laboratory. □

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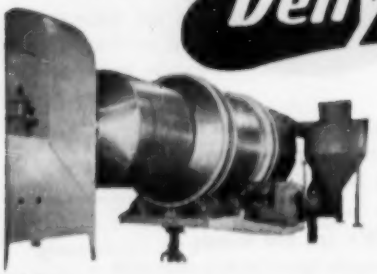
Here is a team for improving your PVC piping: (1) Tube Turns Plastics' socket type PVC fittings and (2) "ttp" Solvent Cement. The combination gives joints as strong or stronger than the pipe itself. Fittings are injection molded by exclusive Hendry process. Cement is simple to apply with a paint brush as shown. For complete details on "ttp" socket and threaded types PVC fittings and flanges, and on "ttp" solvent cement, write Tube Turns Plastics, Inc., Dept. PB-11, 2929 Magazine St., Louisville 11, Kentucky.

TUBE TURNS PLASTICS, INC.
Louisville 11, Kentucky
Call your **TUBE TURNS PLASTICS'** *Distributor*

Chemicals are Dried Quickly, Economically in.... DehydrO-Mat PAT. PENDING



Steam-heated DEHYDRO-MAT
Low temperature, variable-inclination, rubber-tired DehydrO-Mat dries ammonium nitrate and other hard-to-dry chemicals requiring hours of hold-up time.

CONVENTIONAL DRYER
Heavy-duty rotary unit with furnace, burner, breeching and air-handling system. Used for ammoniated granular fertilizers and other chemicals.

Literature and information on request.

EDW. RENNEBURG & SONS CO.
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NUCLEAR NEWS

The Atomic Energy Commission has amended byproduct material (radioisotope) regulations to permit the possession and use under general license of additional types of low-level radioactive sealed sources. The purpose in generally licensing these and similar items is to permit them to be sold without requiring the user to obtain a specific license. The manufacturer, however, must be specifically licensed and must manufacture, test and label the devices and equipment as provided in the license.

The radiation hazard associated with the items has been carefully studied by both the Commission and an advisory committee of radiation experts and determined not to constitute an unreasonable risk to the health and safety of the public. This evaluation was made solely on the basis of radiation safety, and the usefulness of these items was not considered.

The sealed sources placed under general license by the amendment are:

(1) Spark gap tubes and electronic tubes containing not more than 5 microcuries per tube of krypton 85 gas.

(2) Light meters incorporating as a sealed source not more than 200 microcuries of strontium 90, for use in photography.

(4) Ion generating tubes containing not more than 500 microcuries per tube of polonium 210, for use in air conditioning and other equipment.

The amendment also puts under general license small quantities of beta and gamma emitting radioisotopes not heretofore covered by the regulation. □

Seven proposals have been received by AEC from industrial firms for production of refined uranium salts in privately-owned and operated facilities. Proposals were received from: Union Carbide Nuclear Company, Division of Union Carbide and Carbon Corporation, New York, N. Y.; Koppers Company, Inc., and Kennecott Copper Corporation, Pittsburgh, Pa. (Joint Proposal); Dow Chemical Company, Midland, Michigan; Twentieth Century Materials Corporation, Denver, Colo.; Climax Molybdenum Company, New York, N. Y., and Mallinckrodt Chemical Works, St. Louis, Mo. (Joint Proposal); General Chemical Division, Allied Chemical and Dye Corporation, New York, N. Y.; Vitro Corporation of America, New York, N. Y.

The evaluation of proposals is expected to be completed about January 1, 1957. In evaluating the proposals, the overall cost to the government for procuring the desired uranium salts will be of primary consideration. Also to

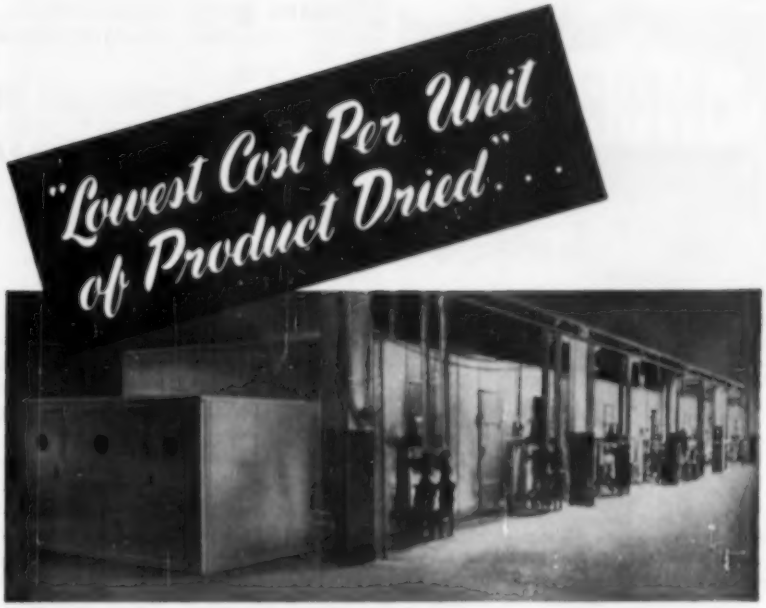
This new nuclear criticality facility of ALCO Products, Inc. at Schenectady, N. Y., is being used to perform experimental reactor studies to check calculations against actual reactor performance and provide new insights into the atom as a power source. Initial work is being done in connection with ALCO's contract to build the Army Package Power Reactor at Fort Belvoir, Va. The facility, which is heavily and elaborately safeguarded, has its core in the reactor room which houses a 2,500-gallon unpressurized reactor water tank.

be considered will be the schedule of deliveries and the feasibility of processes and facilities proposed.

In announcing the program on October 27, 1955, the Commission stated that it was interested in receiving proposals from qualified firms to process uranium ores or concentrates to yield uranium trioxide, uranium tetrafluoride or uranium hexafluoride. Proposals were requested on the basis of a production rate of up to a maximum of 5,000 tons of U_3O_8 equivalent per year over a five-year period, with deliveries to begin about April 1, 1959. Presently, the production of uranium salts is limited to government-owned plants operated for the Commission by contractors. Private participation in this part of the atomic energy program would satisfy the need for increased capacity without expansion of government-owned facilities. □

A program in nuclear science and nuclear engineering education has been inaugurated at Clarkson College of Technology. The program started with the first of an eight session faculty seminar, and a senior undergraduate course in nuclear science will be initiated in February.

Objectives of Clarkson's nuclear program are the development of new courses in nuclear science and nuclear engineering, the inclusion of special nuclear topics in the existing specialized engineering and scientific courses, the acquisition of material for a nuclear library and of equipment suitable for a nuclear laboratory. □



That is the Result EVERY "NATIONAL" CONVEYOR DRYER IS DESIGNED TO GIVE

"NATIONAL" Conveyor Dryers are built to specifications determined by experience gained through years of specialization in the Drying Machinery field. They incorporate many exclusive "NATIONAL" Developments which have established new standards for drying speed and efficiency. Like all "NATIONAL" Dryers, the Conveyor Types are engineered to assure unequalled uniformity and speed under critical drying conditions, and to provide the lowest possible cost per unit of product dried. They can readily be designed for uninterrupted, production-line connection with "NATIONAL" Extruders, Automatic Feeders or other special handling equipment, of either "NATIONAL" or other manufacture.

With "NATIONAL'S" Unique unit construction, there are virtually no limitations as to size or productive capacity of either the Single Apron, Multiple Apron or Combination Dryers. Present installations range from small, compact units, to machines up to 250' or longer. Units can be easily added at any time, to take care of future increases in capacity requirements.
Illustrated above: View from enclosed end of "NATIONAL" fourteen-section multiple-unit Single Apron Conveyor Dryer with three-zone control.

Send for Folder Describing "National" Single and Multiple Apron Conveyor Dryers and Related Equipment

THE NATIONAL DRYING MACHINERY CO.
LEHIGH AVENUE and HANCOCK STREET
PHILADELPHIA 33, PENNA.

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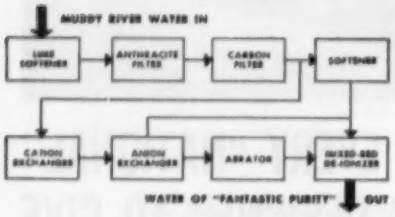
HOW TO
UN-MUDDY
THE WATERS



This block diagram shows a typical arrangement for a power company steam plant that must draw its boiler feed water from a nearby muddy river. The Lime Softener takes out suspended solids, turbidity, alkalinity, and organic matter; the Anthracite Filter removes any remaining turbidity; the Carbon Filter removes the chlorine; the Softener provides process water; the Cation and Anion Exchangers remove the dissolved solids such as carbonates, sulfates, and chlorides; the Aerator takes out most of the CO_2; and the Mixed-Bed De-Ionizer eliminates the remaining 4 or 5 ppm of solids, silica, and 5 ppm of CO_2 — to produce water of "fantastic purity."

ILLCO-WAY PIONEERS IN
PRACTICAL EXPERIENCE

Illinois Water Treatment Company designs and builds *complete, practical, workable systems* such as that shown above — to operate economically on a cost-reducing basis. This work is based on a wealth of practical knowledge gained through constant experience in the specialized field of ion-exchange, starting from the time that the first workable resins became available.

Remember ILLCO-WAY—foremost in the field of ionXchange.

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PROGRAM DEVELOPING FOR EJC NUCLEAR CONGRESS

March 11-15, 1957 event in Philadelphia shaping up.

Program plans for the 2nd EJC Nuclear Congress moved toward finalization at a recent meeting of program representatives which took place in New York, November 2, under the chairmanship of Bruce R. Prentice (General Electric), program chairman.

Program committee representative for A.I.Ch.E. Herbert Isbin (University of Minnesota) reported in some detail the papers now expected to appear in the various symposia under the general subject "The Fuel Cycle." The symposia classifications were first announced in the September, 1956 issue of *CEP*.

The symposium on *uranium and thorium production*, with co-chairmen F. L. Cuthbert (National Lead) and Floyd Culler (ORNL), will likely cover the following: refining of uranium ore concentrates; a fluidized bed process for production of UF_4; recovery of uranium from various materials; production of thorium.

The symposium on *fuel cycle interrelationships*, with co-chairmen E. B. Gunyou (Koppers) and J. C. Robinson (Sylvania), will review the various specialized approaches to the fuel cycle as represented by the fuel fabricator, fuel processor, and the reactor designer.

Fuel manufacture, another symposium subject, will be co-chairmaned by F. Foote (Argonne) and R. B. Briggs (ORNL). Papers will deal with fuel element fabrication and refabrication considerations, and may include oxide fuels and high temperature fluid fuels.

Aqueous spent fuel processing, a symposium to be conducted by R. B. Richards (Hanford), co-chairman not yet announced, will concentrate on the preparation of fuel for reprocessing, in what is called "head-end" steps or processes. Waste treatment and plutonium recovery will come under examination in papers discussing ion exchange, electrolysis, and other processing steps.

Non-aqueous spent fuel processing, under the chairmanship of S. Lawroski (Argonne), will go into in-pile fuel processing loop construction, operation, and experimental results. Another paper will discuss the magnesium extraction process for plutonium separation from uranium. A pyrometallurgical reprocessing plant will be reviewed in conceptual design, as will be a remote fabrication plant.

Economics of the fuel cycle will be covered in a symposium under the co-chairmanship of M. Levenson (Argonne) and J. Hogerton (Vitro). Plu-

Designed as a dual-purpose plant to produce plutonium for Britain's military program and electricity for the National Grid, the Calder Hall atomic power station is the world's first station to produce power from nuclear energy on an industrial scale (See Trends, *CEP*, September, 1956). The forerunner of four identical plants, it will feed 60,000 kws. into the nation's grid, and the experience gained in construction is being used for a program of building twelve commercial nuclear stations during the next nine years.

tonium recycle in a thermal reactor system will be critically examined, as will be the economic potential of ceramic fuel elements. Fuel fabrication costs, and chemical processing cost analyses will round out this session.

H. A. Ohlgren (University of Michigan) has organized two special sessions, which A.I.Ch.E. is sponsoring, on heat transfer. One of these will be on *heat transfer and heat evolution*, and will involve measurement of heat transfer coefficients by a method of cyclic temperature variations. Some work will be reported on liquid metals heat transfer coefficients. Natural convection will also be reported on. Heat evolution will be dealt with in connection with gamma-heating calculations.

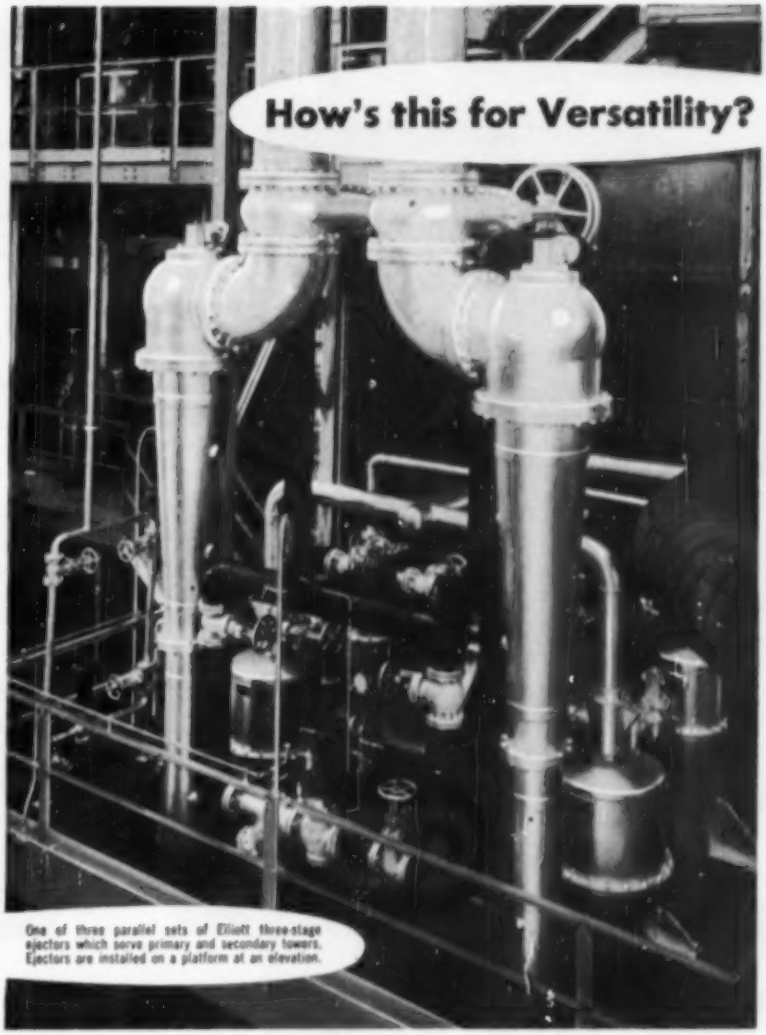
Problems relating to heat transfer, the second of the heat symposia organized by Ohlgren (chairmen for either session are not yet announced) will cover some work that has been completed on transients, and on burn-out testing of fuel elements. Mechanical and thermal problems of water cooled nuclear power reactors will also be discussed, as will thermal stresses in reactor fuel elements.

Further details on the program as a whole, as well as the portion sponsored by A.I.Ch.E., will appear in *CEP* as the information becomes available.

The Oak Ridge Institute of Nuclear Studies' pioneer "traveling teachers" now have their own covered wagons—of the most up-to-date type. The seven representatives of the Oak Ridge Traveling Science Demonstration Lecture Program are now visiting schools throughout the nation in 1957 Ford Country Sedans—fully equipped six-passenger station wagons with Thunderbird motors, provided through the courtesy of the Ford Motor Company.

The purpose of the Oak Ridge Traveling Science Demonstration Lecture Program is to stimulate interest in science and science-teaching careers on the part of the nation's secondary-school students, as an aid to overcoming the great disparity between the supply of, and demand for, scientifically trained personnel in industry, education, research, and other fields. □

Another entry into the fast-growing atomic energy industry is Superior Tube Co. The small diameter tubing producer has formed a Nuclear Products Division. Products of the new division will include shaped control rod channels, assembly channels and control rods. In addition to reactive metals (titanium and zirconium alloys), the division will process stainless steels, high nickel alloys and rare metals having special nuclear properties. □



One of three parallel sets of Elliott three-stage ejectors which serve primary and secondary towers. Ejectors are installed on a platform at an elevation.

ELLIOTT *Steam Jet* EJECTORS

This installation in a large oil refinery called for three parallel sets of Elliott three-stage steam jet ejectors. Parallel ejectors permit one set to be shut down during reduced rates, making for greater economy in steam consumption. They operate on 100 psig steam, maintaining vacuum on both the main unit and the secondary tower. Tower pressure is controlled by recycling gases from the third-stage ejector discharge back ahead of the first stage ejector.

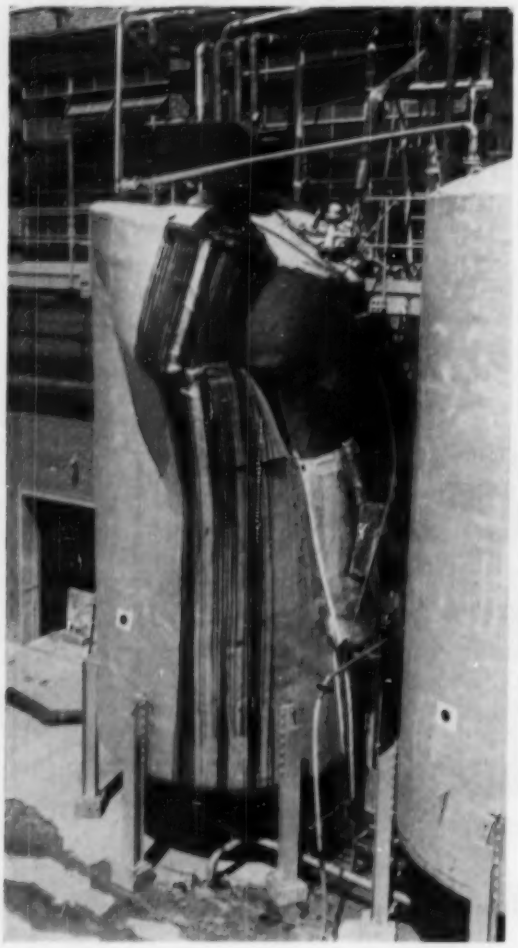
Whenever vacuum is required, it pays to utilize the know-how of Elliott ejector specialists. Contact your Elliott representative or write Elliott Company, Jeannette, Pa. for descriptive bulletins.

ELLIOTT Company

GS-1

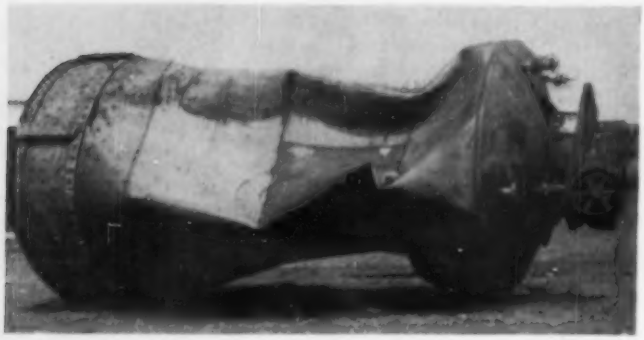
STEAM TURBINES • MOTORS • GENERATORS • DEAERATING HEATERS • CONDENSERS • CENTRIFUGAL COMPRESSORS • REFRIGERANT • TUBE CLEANERS • STAMPINGS

CEP CAMERA . . .



IMPLOSION!

Case study showing what can happen with inadequate vent system. This 20,000 gallon tank insulated with foam glass had been steamed for 30 minutes using free steam from 35 lb./sq.in. source. A 2-in. vent line was connected to a 4-in. flanged opening in top of tank and vent extended to within 2-ft. of ground. There were no valves in vent line. 45 minutes after steam was shut off, process liquors at 80° F. were pumped into tank. Collapse occurred after 3,400 gallons had been added. Operation was standard, had been performed many times. Immediately after accident, vent line was found to be unobstructed. Photo below shows tank with insulation removed.



NEW YORK

Section's 1-day meeting saw dynamic tax specialist Paul W. Smith (Carbide) making a point while J. C. Armstrong (consultant), G. J. Marlowe (Scientific Design), and Whitney Weinrich (Cox & Weinrich) look on. Below, meeting committee members T. M. Richey, R. F. Fremed, T. M. Jackson, Jr., J. F. Lawrence, J. W. Colton, R. K. Gitlin, & H. Y. Krinsky.

GALVESTON

South-Texas 1-day meeting, in semi-tropic Galveston, as shown by (top, clockwise): Committeemen C. L. Fitzgerald, Jr., J. F. Conlon, K. S. McMahon, J. H. Presnell, E. E. Ludwig, Ted Workman, & J. C. Wrobleski . . . a "mustachioed" moment of gaiety at banquet, attended by 500 . . . cocktails on the Galvez' patio, by pool . . . commercial exhibits . . . B. F. Dodge & C. A. Stokes; E. W. Comings & W. A. Cunningham in tropic garden (note bananas). Photos by Clarence Downtein, Carbide, Texas City.

50TH ANNIVERSARY

Seen at recent committee meeting, C. G. Kirkbride (chmn.), F. C. Frery, W. L. McCabe, H. F. McConomy, F. J. Curtis, W. G. Whitman.

OUR MUCH-HONORED PRESIDENT

Receiving the honorary degree of Doctor of Science from the University of Pennsylvania. In picture are: President Gaylord P. Harnwell; Henry Cabot Lodge, Jr., U. S. Representative to U. N.; T. S. Gates, Jr., Under Secretary of Navy; Kenjiro Matsumoto of Tokyo, industrialist and Penn alumnus; Walt Whitman, president of A.I.Ch.E., head of Chemical Engineering at M.I.T., & secretary-general of U. N. Geneva Conference on Atomic Energy; & Simon S. Kuznets, professor at Johns Hopkins. Dr. Whitman also received an honorary degree from Centre College of Kentucky.

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VANTON!

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LINES OF
PLASTIC
PIPE,
FITTINGS
AND
VALVES

(P) PVC (Unplasticized, Unmodified, Polyvinyl Chloride)
For outstanding chemical resistance.

(S) Styrene Copolymer
For exceptional impact strength.

(N) Buna N
(Acrylonitrile-Butadiene)
For excellent temperature resistance.

Vanton, with many years of pioneering experience in the manufacture of plastic pumps, now makes available pipe, fittings and valves in the above basic materials. These plastic compounds have been selected to offer as broad a coverage as possible with respect to the application requirements of the process industry.

- Excellent corrosion resistance
- Non-contaminating properties
- Excellent mechanical performance
- Ease of installation
- Excellent electrical and insulating properties
- Insulating properties
- Economical
- High temperature resistance

Write for Catalog PF 101

VANTON
PUMP & EQUIPMENT CORP.
201 Sweetland Ave. Hillside, N. J.
Division of Cooper Alloy Corporation

CHEMICAL PUMP STANDARDIZATION STILL UP TO YOU

Specialization of chemical plant uses still poses problems for both user and manufacturer; reception of standardization not as rapid as some might think, said W. D. Staley of Duriron Co., speaking before the Seventh National Conference on Standards held recently in New York by the American Standards Association.

Standardization of centrifugal pumps for chemical plant service has long been recognized as desirable by users as well as by manufacturers (See CEP, April 1956). But how well are standardization attempts being received by the designers and operators of chemical plants? Said Staley—"Even though we have made a vigorous effort to arrive at a standard chemical pump which would be acceptable to a majority of the users of this pump, our records show that a high percentage of the pumps which we are shipping at the present time have some feature or accessory which does not comply with our company standard."

This situation is not thought to be indicative of any significant trend, but shows, rather, that the users have as yet perhaps not taken full advantage of the standardization offered them by the manufacturers.

This is not unusual in the history of standardization efforts in the chemical industry. Valves for the industry were originally produced with face-to-face dimensions conforming to the ideas of the designer only and not to any industry standard. In spite of many unpleasant experiences in the field, there was no concerted effort by manufacturers or users to work out relatively simple standard face-to-face dimensions.

It was only a few years ago that certain large users insisted that manufacturers come to some agreement in this respect. As a result, today we have standards which are almost universal in the industry. In this case, although the long range benefits to both user and manufacturer were obvious, many years went by before this could be accomplished through the insistence of the chemical industry and the cooperation of valve manufacturers.

The trend toward the standardization of centrifugal pumps is illustrated by the experience of the Duriron Co. in this field. Previously, the company found themselves in such a position that they were forced to produce a standard design for their own company, a plant standard for one chemical company, a modified design for a second company, and a unit with other features for a third company. This sort of scheduling inevitably resulted in short production runs, multiple stock of finished goods, and longer delivery times which in many cases resulted in customer dissatisfaction.

Then an independent survey among pump users revealed certain features on which there was wide agreement between users. As a result of this survey, the Duriron Co. decided to develop and produce a complete new line of pumps incorporating many of the desirable features indicated by the survey.

The current work of ASA Sectional Committee B73 on Centrifugal Pumps for Chemical Industry Use is definitely a step in the right direction since it will establish a standard on an industry-wide basis rather than merely on a company basis.

It is recognized that pump uses in the chemical industry are probably more diversified than in many other industries. Therefore the goal of complete standardization is a more difficult one. Any standards which are evolved should in no way restrict individual initiative on the part of the manufacturer. Such standards should be defined in terms of size, essential dimensions, features, and performance rather than design details. Thus, benefits will be realized by both user and manufacturer while, at the same time, development of new techniques and materials as well as new design developments will be encouraged.

NEWLY-FORMED INTERNATIONAL CONGRESS ON CATALYSTS HOLDS MEETING

First Annual meeting of the new Congress hears E. J. Houdry, longtime expert in catalysis.

Catalytic oxidation can free the engineer from the limitations imposed upon him by conventional flame combustion, according to E. J. Houdry, chairman of the board of Oxy-Catalyst, Inc., and original founder of the Houdry Process Corp., speaking to the First International Congress on Catalysis, Sept. 13 in Philadelphia.

Oxidation catalysts, Houdry explained, initiate burning of fuel mixtures under conditions not normally suitable for combustion. Since they are in a sense chemical burners that support

combustion of mixtures too dilute or too cold to be ignited by flame, they have proven to be highly efficient devices for air pollution control of industrial plant stacks and engine exhausts, and for the recovery of heat from waste gases.

Houdry also stated that there is reason to think that catalysts in the human body —known as enzymes—hold the key to both cancer and the deterioration of aging.

The newly organized Congress elected H. Heinemann of Houdry Process Corp. as president.

STUDENT CONTEST PROBLEM PRIZE AWARDS

The A.I.Ch.E. announces the following award winners for the 1956 Student Contest Problem:

Problem contest prize winners, l. to r. Don Cianci, Maurice G. Lorenz, and David Kearns.

Don Cianci, First Prize, University of British Columbia, Vancouver, B. C., Canada. Now with Shell Oil Co. of Canada, Ltd., Montreal.

Maurice G. Lorenz, Second Prize, Purdue University, Lafayette, Ind. Now in Purdue's Graduate School with part-time instructorship.

David Kearns, Third Prize, University of Illinois, Urbana, Ill. Now assistant and graduate student at the University of California.

J. C. Vogt, Honorable Mention, Fenn College, Cleveland, O. Now with Standard Oil Co. (Ohio).

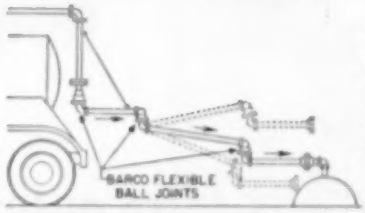
John M. Wetz, Honorable Mention, Oklahoma A&M, Stillwater, Okla. Now a graduate student at Purdue University.

Dale R. Albright, Honorable Mention, Lafayette College, Easton, Pa. Now with Bakelite Division, Union Carbide and Carbon, Bound Brook, N. J.

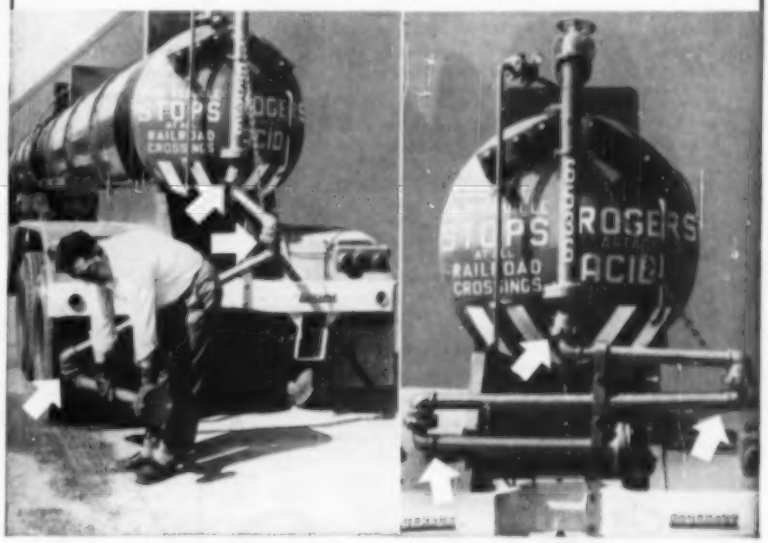
A new Pipeline Division has been established in the American Society of Civil Engineers. □

The semi-annual meeting of the Air Pollution Control Association will be held at the Rice Hotel, Houston, Tex., Dec. 3, 4 and 5. Symposia will cover the odor problem, the sulfur problem and the dust problem. □

For SAFETY and Lower Costs in Handling Sulfuric Acid



The accompanying sketch shows how three Barco Ball Joints in unloading (or loading) line provide complete flexibility for making connections in any position. Note how line folds neatly on back of truck when not in use (photo below).



Barco Flexible Ball Joints Replace Hose

Two near-accidents with hose blowing out some time ago, while handling sulfuric acid with 30 psi air pressure, caused Rogers Cartage Co. of Chicago to change to Barco Flexible Ball Joints (with malleable iron casing and stainless steel ball) in loading lines on some 15 big trucks serving many chemical, petroleum, steel, and other customers in the Midwest area. Since making the change, Mr. Jack Kidder, Rogers Safety Manager reports that there have been no failures and little or no maintenance on the joints. Cost for frequent hose replacement has been eliminated. *Inquiries are invited, address Barco. Ask for Catalog 215B.*

ADVANTAGES

NO METAL-TO-METAL CONTACT BETWEEN MOVING PARTS — No ball bearings to corrode.

CHEMICALLY INERT GASKETS — No. 11-CT for corrosive service. Suitable for many liquid chemicals.

PRESSURE-SAFE! FIRE-PROOF! — Unequalled for SAFETY, DURABILITY, ECONOMY.

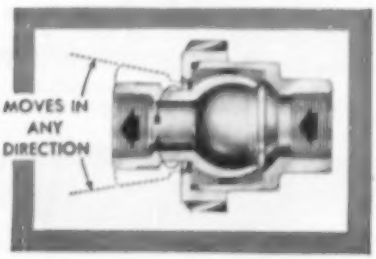
CHOICE OF STYLES — Angle or straight. Sizes ¼" to 6". Available in choice of metals, including stainless steel and special alloys.

APPROVED — By leading chemical manufacturers and trucking associations.

BARCO

BARCO
Manufacturing Co.

560M HOUGH STREET
BARRINGTON, ILLINOIS
In Canada: The Holden Co., Ltd., Montreal



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Amersil processes for producing fused quartz and silica of the *highest possible purity*, in fabricated laboratory and production equipment—make Amersil the primary supply source for all industrial applications where such critical purity is a factor.

A fine service plan is keyed to your requirements. Here, complete ranges of standard apparatus, crucibles, trays, cylindrical containers and tubing (up to 25" diam.) are available for prompt delivery. Amersil engineers are available to assist in developing special equipment to individual requirements.

Catalog and technical data available upon request.

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- OPTOSIL
- HOMOSIL
- ULTRASIL

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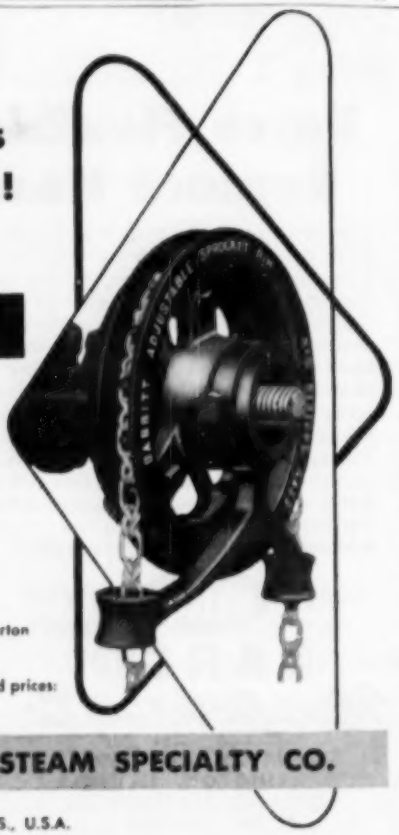
Adjustable
SPROCKET RIM
with Chain Guide

- Eliminate dangerous catwalks, ladders, balconies, boxes, stools, etc.
- Prevent accidents, protect personnel
- Reach inaccessible areas easily
- Operate every valve from plant floor
- Easy to install and operate
- No maintenance, first cost, only cost
- Easy instructions with each unit
- Packed, completely assembled, one to a carton
- Fits any size valve wheel
- Your supplier carries complete stock
- Write for new descriptive Catalog sheet and prices:



Babbitt STEAM SPECIALTY CO.

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FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

■ **ANNUAL—BOSTON, MASS.**

Dec. 9-12, 1956. Hotel Statler.

See page 46 for final round-up on this important meeting, plus pictures of those who will be presenting papers.

In Boston: Paul Revere, Old North Church.

Filtration

CHAIRMAN: F. M. Tiller, U. of Houston.
The flow of liquids through compressible media with experimental and theoretical papers.

Low Temperature Techniques

CHAIRMAN: Clyde McKinley, Air Products Inc.
Papers dealing with gas prepurification for low temperature processing and the low temperature aspects of heat exchange, refrigeration, distillation and liquid-vapor equilibria, and the properties of materials.

The Sales Engineer in Chemical Engineering

CHAIRMEN: W. E. Hesler, Swenson Evaporator Co., E. D. Kane, Cuno Eng. Corp.
Three Panels: "Introducing Mr. Chemical Sales Engineer," "Training the Chemical Sales Engineer," "Performance Yardstick of the Chemical Sales Engineer."

Laboratory Facilities for Nuclear Engineering Education

CHAIRMAN: Joseph J. Martin, U. of Mich.
Presentation of costs and uses of nuclear equipment in various educational curricula.

Chemical Engineering in the Pulp and Paper Industry

CHAIRMAN: E. C. Bowen, The Bowen Corp.
Co-chairman: L. C. Jenness, Univ. of Maine.
Session of technical papers followed by discussion panel of industrial leaders.

Advancing the Automatic Control of Chemical Process Plants

CHAIRMAN: Wayne Alexander, Monsanto Chem. Co. Co-chairman: David M. Boyd, Univ. Oil Products. A C.E.P.-sponsored "session-in-the-round" evolving company practices and defining process design and personnel training needs.

Owning Your Own Business

Sunday afternoon panel discussion.

■ **WHITE SULPHUR SPRINGS, W. VA.**

March 3-6, 1957. Greenbrier Hotel.

TECHNICAL PROGRAM CHAIRMAN: S. G. Friedman, E. I. duPont de Nemours & Co., Benger Lab., Waynesboro, Va.

Computers in Chemical Company Control

CHAIRMAN: W. M. Carlson, du Pont, Engineering Service Div., Newark, Delaware.
The use of large-scale computers in handling

(Continued on page 124)

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5	10"	15"	18.00	20	18"	18"	40.00
8	12"	16"	22.00	26	18"	24"	45.00
8	12"	20"	24.00	30	18"	28"	49.00
10	12"	24"	26.00	40	18"	36"	59.00
12	12"	24"	23.00	50	18"	48"	69.00
9	10"	24"	21.00	27	22"	18"	49.00
7	9"	24"	26.00	30	22"	20"	53.00
10	16"	12"	28.00	55	22"	36"	70.00
12	16"	14"	33.00	73	22"	48"	83.00
15	16"	18"	40.00	85	28"	32"	76.00
20	16"	24"	49.00	95	28"	36"	98.00
30	16"	36"	59.00	125	28"	48"	125.00
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FUTURE MEETINGS

(*Continued from page 122*)

MEETINGS SYMPOSIA

payrolls, billing and ordering, sales forecasting, production control, etc.

Futures in the Chemical Industry

CHAIRMAN: R. E. Chaddock, Hercules Powder Co., Virginia Cellulose Dept., Wilmington 99, Del. Co-chairman: Geo. Rieger, Diamond Alkali Co., Cleveland Ohio.

Scientists, Engineers & Management Decisions—A Problem in Teamwork

CHAIRMAN: G. D. Creelman, Creelman Associates, 10524 Wilbur Ave., Cleveland 6, Ohio. The psychological factors which must be considered to assure effective functioning of Operations Research (scientific decision-making) teams.

■ **PHILADELPHIA, PA.**
March 10 through 16, 1957.
EJC Second Nuclear Engineering and Science Congress & Exposition.

■ **EVANSTON, ILL.**
April 8-9, 1957. Northwestern University.
Joint Instrument Symposium in cooperation with Instrument and Regulators Division of American Society of Mechanical Engineers.

■ **ST. LOUIS**
June 3-7, 1957.
Golden Jubilee Meeting, Air Pollution Control Association; sponsoring societies include A.I.Ch.E. (Tuesday, June 4 will be A.I.Ch.E. day.)
Methods of Analysis; Instrumentation; Atmospheric Reactions, Photochemical & Other; Aerosol Formation & Control; Progress in Air Pollution Control Equipment & Methods; and Human & Economic Goals for Engineers in Air Pollution Control will be treated.

■ **SEATTLE, WASH.**
June 9-12, 1957. Olympic Hotel.
TECHNICAL PROGRAM CHAIRMAN: James G. Knudsen, Dept. of Chem. Engrg., Oregon State College, Corvallis, Oregon.

Industry's Role in University Programs on Nuclear Engineering

CHAIRMAN: John Kaufmann, Div. of Reactor Development, U. S. Atomic Energy Commission, Wash., D. C.

Chemical Engineering Data and Calculation Methods

CHAIRMAN: W. C. Edmister, Calif. Research Corp., Richmond Laboratory, Richmond, Cal.

Filtration

CHAIRMAN: To be named.

■ **STATE COLLEGE, PA.**
August 11-14, 1957. Pennsylvania State University.
First National Conference on Heat Transfer, featuring Applied Heat Transfer. Sponsors: A.I.Ch.E., A.S.M.E., & College of Eng. & Arch., Penn State Univ.

James N. Addoms, Atlas Powder Co., Wilmington 2, Delaware, is A.I.Ch.E. program chairman. Correspondence on proposed papers is invited up to December 1.

■ **BALTIMORE, MD.**
September 15-18, 1957. Lord Baltimore Hotel.
TECHNICAL PROGRAM CHAIRMAN: R. L. Copson, Mutual Chemical Co. of America, 1348 Block St., Baltimore 31, Maryland.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Engineering Dept., Ill. Inst. of Tech., Chicago 16, Ill.

(*Continued on page 125*)

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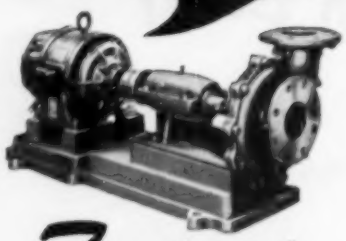

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FREDERICK PUMPS

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Direct Operating Labor Costs
CHAIRMAN: John Happel, Chem. Engrg. Dept., New York University, University Heights, N. Y. 53.

ANNUAL—CHICAGO, ILL.
December 8-11, 1957. Conrad Hilton Hotel.
TECHNICAL PROGRAM CHAIRMAN; Henry F. Nolting, Standard Oil Co., 2400 New York Ave., Whiting, Ind.

Fluidization of Solids
CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.
Flow characteristics, rate of entrainment and heat transfer; fluidized reactors vs. fixed and moving bed reactors.

Effective Cost Control in Process Operations
CHAIRMAN: C. W. Nofsinger, The C. W. Nofsinger Co., 906 Grand Ave., Kansas City 6, Mo.

Evaluation of Projects from the Original Idea to the Investment Stage
CHAIRMAN: C. W. Nofsinger (see above).

Chemical Engineering Abroad
CHAIRMAN: Shelby Miller, Chem. Eng. Dept., University of Rochester, River Campus Station, Rochester 20, N. Y.

Corrosion Resistant Alloy Materials of Construction
CHAIRMAN: G. Fred Ours, Carbide and Carbon, Charleston, W. Va.

Laboratory and Pilot Plant Techniques
CHAIRMAN: G. W. Blum, The Goodyear Tire & Rubber Co., 1485 E. Archwood Ave., Akron 16, Ohio.

UNSCHEDULED SYMPOSIA

Correspondence on proposed papers is invited.

Centrifugation
CHAIRMAN: James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kan.
The theory and quantitative aspects of centrifugation.

Size Reduction
CHAIRMAN: Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.

Filtration & Centrifugation
CHAIRMAN: Horace Hinds, Jr., Corn Products Refining Co., Box 345, Argo, Ill.

Chemical Engineering Process Dynamics as They Affect Automatic Control
CHAIRMAN: David M. Boyd, 315 Ridge Ave., Clarendon Hills, Ill.

Ethylene Manufacture
CHAIRMAN: Hermann C. Schutt, 201 Devonshire St., Boston 10, Mass.

Dry Classification of Solids
CHAIRMAN: D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.

Saline Water Conversion
CHAIRMAN: W. L. Badger, 309 So. State Street, Ann Arbor, Michigan.

Statistics in Chemical Engineering
CHAIRMAN: John C. Whitwell, Princeton University, Princeton, N. J.

Education of Chemical Engineers
CHAIRMAN: F. M. Tiller, Dean of Engrg., University of Houston, Cullen Blvd., Houston 4, Texas.

New Chemical Engineering Construction Techniques
CHAIRMAN: S. A. Guerrieri, The Lummus Co., 385 Madison Ave., N. Y. 17.

Mineral Process Engineering and Mineral Economics
CHAIRMAN: L. A. Roe, International Minerals & Chemical Corp., 20 North Wacker Drive, Chicago 6, Ill.

Foams and Froths
CHAIRMAN: J. L. York, Ramo-Wooldridge Corp., 8820 Bellanca Ave., Los Angeles, Calif.

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After considerable investigation, and experimentation with four different types of blending equipment, this company selected a Paul O. Abbé Double Cone Blender with a special plastic lining. Due to the low coefficient of friction of the plastic, the problem of the material adhering to the sides of the Mixer was completely eliminated. Homogeneous mixing resulted, and batches discharged readily.

The manufacturer now states: "The Blender performs as represented and you gave us excellent service. The equipment has been installed for two years. The plastic liner has been checked periodically and it shows no sign of wear."

Whether your particular blending difficulty is due to the adhesion of material or not, the long and varied experience of Paul O. Abbé is available to help you solve it. Write us today, outlining any grinding or mixing problems you may have.

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271 Center Ave. **Little Falls, New Jersey**

A New York Meeting Report

With regard to costs . . .

CASH FLOW METHOD TERMED IMPORTANT AID TO INTUITION

Congress' examination of depletion allowances, tax graduated to bigness, seen to affect new plant planning.

"Sometimes we analyze all the negative points of a project so thoroughly that we dampen that vital spark—enthusiasm. I would rather go ahead on a project on which I was 75% sure, with the organization full of enthusiasm, than on one 99% sure but with an organizational attitude of indifference and passive tolerance."

With this statement, Wm. B. Plummer, himself a seasoned executive in the process industries (immediate ex-president of Indoil), summarized at the recent 1-day annual meeting of the N. Y. Section of A.I.Ch.E. his belief in the need for economic evaluation schemes that will most closely reflect real probabilities, will not themselves produce artificially pessimistic or optimistic conclusions.

With analysis of cash flow being the technique favored by Plummer and others at the session, *CEP's* readers will find convenient reading the definitive article by Weaver & Reilly entitled "Interest Rate of Return" which begins on page 405 of the October issue.

The Board of Directors, Plummer went on to explain, is essentially concerned with future profits of an organization. The primary problem with most Boards of Directors is not to find something to do with the company's surplus funds, but rather how to allocate capital between projects which are all to some greater or lesser extent desirable or necessary. In all too many cases, widely different projects are compared by some over-simplified method such as payout time. Many other factors must be considered.

In above photo, management-conscious Wm. B. Plummer (consultant) is at mike while John Happel (N. Y. University & chairman), W. P. Neidig (White, Weld & Co.), John C. Armstrong (consultant), and G. J. Marlowe (Scientific Design) give their attention. Not shown: costimators Whitney Weinrich (Cox & Weinrich) & P. W. Smith (Carbide). For these and others, see page 118.

Taxation—Major Factor Now

Taxation and its effect on engineering costs is a subject which is today a major factor in cost estimation, so much so, as P. W. Smith, manager of the Tax Department of Union Carbide, pointed out in his paper on Depletion Allowances, that the chemical engineer would do well to check in with his tax expert when making decisions between "capitalizing" and "expensing."

With regard to trends in depletion policies, Smith predicts that with the possible exception of the steel industry, it appears that the system of granting tax deductions to projects desirable from a defense standpoint might be abandoned, unless, of course, the mid-east fracas brings unexpected changes.

Today, plans for the construction of new chemical plants, in addition to other tax factors, must include consideration of potential additional costs that would result from enactment of the various proposals before Congress. In addition to proposals which might reduce the percentage depletion allowance, a new method of taxing corporations has been proposed entitled "full rate graduation." This calls for a graduated rate structure for corporations similar to that for individuals. The large corporations would pay substantially higher percentages. That such actions would dampen the enterprising spirit of the larger organizations seems obvious.

Other Problems

Pointing out that logical procedures for estimating maintenance budgets and controlling actual expenditures have not yet been established in many companies, J. C. Armstrong, vice president of George S. Armstrong and Co., New York, went on to discuss Establishing and Controlling Maintenance Budgets. The factor often used, percentage of capital investment, is generally unsatisfactory. Armstrong proposed instead, that regular maintenance and regular depreciation charges be considered together since they refer to the total expenditures necessary to keep equipment in up-to-date operating condition.

Contrasting Design Philosophies

In the petroleum and petrochemical industries, characterized as they are by continuous processes involving large scale operations and very low storage capacity for intermediate products, any down time results in considerable economic loss. For this reason, process designers use automati: controls widely, as well as spares and by-passes in order to provide maximum reliability. So reported Whitney Weinrich (Cox & Weinrich), who went on to add that, on the other hand, older type chemical plants and those operating on a smaller scale are often characterized by semi-continuous and batch processes. Here, multi-purpose units are often employed, shut-down is not as serious, and since the profitability is often less than with the petroleum or petrochemical units, capital equipment is not as elaborate.

Finally, there is the simple equipment of the low-profit-margin mining industry where capital costs are kept at a minimum. It is likely, however, that some of the modern solvent extraction, ion exchange processes and other chemical engineering techniques will be introduced into this field and significantly change the cost estimation procedures.

Exactly how to finance a chemical venture was treated by C. P. Neidig, repeating his important talk at the Los Angeles national meeting which was printed in full in July *CEP*.

The simplest, or "quickie" cost estimate can be prepared in 10 to 50 hours. On the other hand, the most elaborate estimate may require 1,500 to 7,500 man-hours of engineering design, drafting and estimating as well as considerable clerical effort to produce a report for the careful scrutiny of all interested parties, according to O. J. Marlowe (Scientific Design). Which makes us wonder, what does a 7,500 man-hour estimate cost?

News of the Field
FROM LOCAL SECTIONS

CONSTRUCTION BUSINESS, FREEZE-DRYING, AND SPACE TRAVEL AMONG SUBJECTS AT LOCAL MEETINGS

The integrated engineering-construction business exists largely because of the tremendous pressures on the petroleum and chemical industry to get things done in a hurry, explained B. B. Kuist, Fluor Corp., speaking to the September meeting of the **Twin City Section** (*E. J. Murray*). Although the engineering construction business did not really get going until the thirties, it now does about two-thirds of the annual $1.4 billion petroleum and chemical construction. With time the essential factor in their success, the engineering construction companies work with the closest possible coordination of engineering, buying of materials, and construction. Steps are overlapped, there is no waiting for one step to be completed before the other is begun.

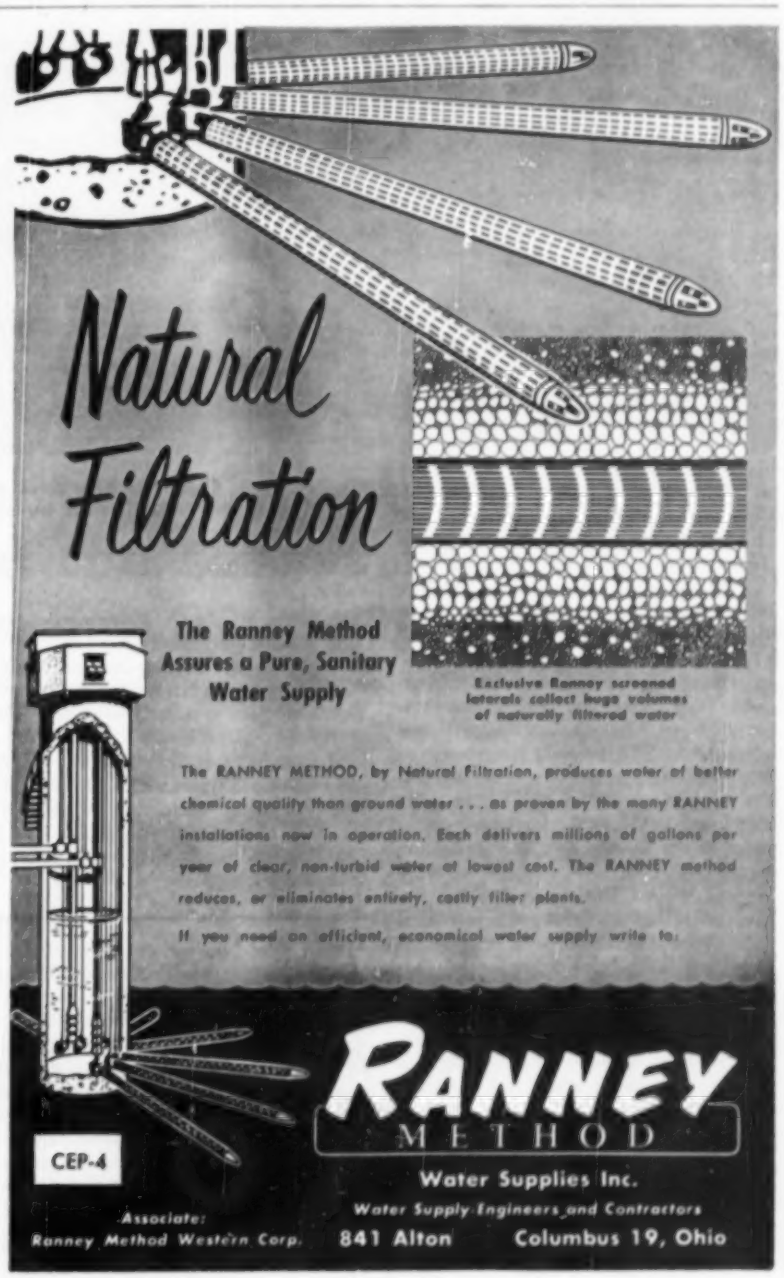
While there have long been acceptable drying methods for fruits and vegetables, there was no such method for meat until the development of "freeze-drying." J. C. Harper, Univ. of California, speaking to the September meeting of the **Southern California Section** (*R. D. Sheeline*), explained that in freeze-drying the food is first frozen, then placed under high vacuum (about 1 mm Hg). Drying is accomplished solely by sublimation of ice. The method has been used in drying such materials as blood serum and antibiotics, and when it is applied to meat there is no migration of soluble materials to the surface nor any signs of "case hardening." The meat rehydrates rapidly in water and is hard to distinguish from fresh meat.

Nitroparaffins

In only 15 years the development and production of nitroparaffins has increased by eight times. In fact, R. S. Egly, Commercial Solvents, pointed out in his talk to the September meeting of the **El Dorado Section** (*D. S. Thomas*), the first patent in the entire field was issued in 1935. The nitroparaffins are good solvents, have recently found application as selective solvents in the separation of naphthenes, aromatics and aliphatics. They are under investigation as rocket fuels because the nitrate radical contains all the oxygen needed for combustion. The nitroparaffins could possibly make excellent commercial explosives since they are all but impossible to detonate unless mixed with an amine and set off with a blasting cap. By reacting the nitroparaffins with various chemicals, products can be produced of use in the fabric industry, the paint, insecticide, and many other industries.

Too many gifted students are not interested in becoming engineers because the price in work and effort is too great. This was the consensus of a panel of high school educators at the September meeting of the **Northern California Section** (*J. W. Casten*). Great emphasis was placed by panelists on the necessity for research programs investigating

(*Continued on Page* 134)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A South Texas Meeting Report

Plasti-prognosticators C. A. Stokes (Texas Butadiene), Henry Groppe (Petrotex Butadiene), and John Livingston (consultant, N. Y.).

Now $1 billion . . . to double by 1961

RAW MATERIALS FOR

PLASTICS & SYNTHETIC RUBBER

BOOMING CHEMICAL ENGINEERING ACTIVITY

Sudden appearance of new ethylene polymerization processes at a time when an enormous supply of ridiculously low-priced (5¢/lb.) ethylene is available; sale to private industry of the government synthetic rubber plants which are being rapidly expanded—these two highly significant situations enable man for the first time in history to look forward to an adequate supply of rubber at a stable low price, and in an atmosphere of confidence in the future of plastics to the degree that $-millions are being poured into research. These and other descriptions of an almost boundless future for plastics raw materials (largely produced on the Gulf Coast) were cited by a panel on "trends in plastics and synthetic rubber" conducted by C. A. Stokes, Texas Butadiene & Chemical Corp., at the recent annual one-day meeting of A.I.Ch.E.'s South Texas Section at Galveston.

Ethylene, vinyl chloride (made in part from ethylene), butadiene, and styrene (with ethylene contributing the vinyl group), are the four really large volume raw materials for polymerization, cited John Livingston, wartime Rubber Reserve Corp. technical director, now consultant. That sizeable numbers of chemical engineers play a large part in the production of these raw materials is evidenced by Stokes, who believes that most of the members of the profession in the Gulf Coast area (one of the large regions of A.I.Ch.E. membership) derive their incomes from such activities.

Because of this enormous stake in the raw materials, chemical engineers came in large numbers and from considerable distances to hear of competing processes for making raw materials, trends in end-use product growth, and competition among the end products for some of the same plastic and/or rubber markets.

Already the plastics materials industry is a 3 billion pound/year venture, representing $1 billion/year product value, and Stokes predicted that this volume will double in five or six years. The synthetic rubber materials industry, about 2/3 the size of plastics materials at present, is expected to double in both volume and dollars in 6 to 8 years.

By comparison, the total chemical output in 1956 will be about $8 billion, which means the plastics and synthetic rubber groups together account for about 1/5 of the total dollar value output of chemicals.

"Who knows what the growth rates of synthetic rubber consumption can be under these conditions . . . who can dare be conservative?" asked Stokes.

"It is little wonder," commented Stokes, "that we as chemical engineers in the Gulf region want to discuss what lies ahead in the raw materials for this tremendous market."

Largest plastics-volume growth will come from the home building field, predicted plastics-use expert W. T. Cruse, Society of Plastics Industry, who quoted from *House and Home* magazine the following timetable for the American home of the future:

Consider the raw materials requirements indicated by this timetable . . .

1956 Interior surfaces, coatings.
1957 Pipe, hardware, fixtures, luminous ceilings.
1958 Partition panels as now used in commercial buildings.
1959 Whole walls (non-load bearing), plumbing fixtures.
1960 Complete windows, prewired, etc. ceiling panels.
1961 Complete bathroom units with pipes & fixtures molded in wall.
1962 Complete mechanical cores that can be traded in like autos.
1963 Full floor units incorporating ducts & wiring.
1964 Unitized kitchens whose components may be traded in.
1965 Whole houses in packaged room units.
1966 Solar heated and powered units with plastic collectors.
1967 Stabilized soil housing; roofing held by inflated plastic tubes, vacation & military housing by mixing soil & plastic at site.
1968 Plastic domes to cover total living unit, including gardens. Controlled "climates" all the year 'round.

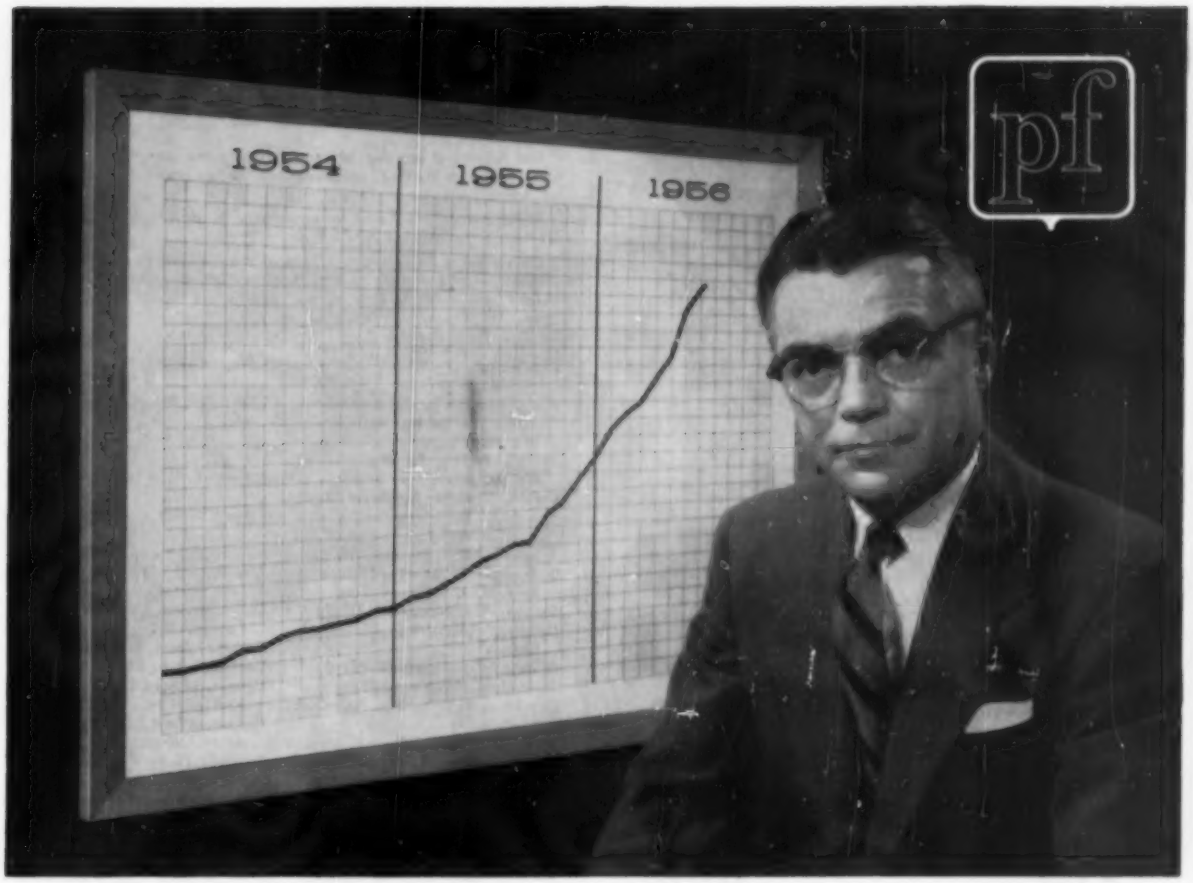
Polyethylene, wheel-horse of the big tonnage plastics of the future (now 0.3 billion lbs./yr., expected to undergo a +364% increase to 1.4 billion pounds by 1961), can be made into physically superior grades by Phillips' Marlex process, according to data presented by B. T. Boeke of Phillips Chemical. Ziegler polyethylenes will appear on the market likewise tailored to dramatic new property ranges, reported Goodrich-Gulf's v.p. Paul W. Cornell, whose firm is currently engaged in preparations.

Other plastics already in big scale production, with growth predictions based on 1955-1961, are, according to Stokes, vinyls (+155%), fluorocarbons (+300%) epoxides (+228%), polyesters (+85%), phenolics (+31%), with polystyrene reversing the trend (−8%).

Plastics to watch, and rated by Stokes as "newcomers"—polyurethane, silicone, polyisoprene, and polybutadiene; "dark horses"—polysulfide, acrylics, and chlorosulfonated polyethylene.

The all-day meeting included several other sessions in addition to that reported here. These will be covered in subsequent issues.

For pictures, details, see page 118.



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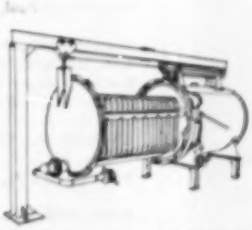
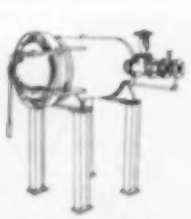
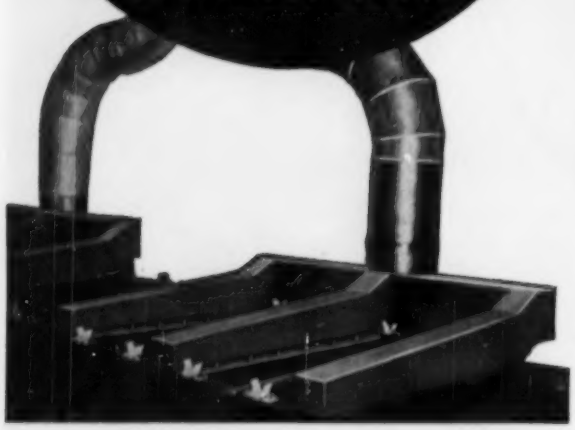

HORIZONTAL LEAF FILTERS


HORIZONTAL BATCH FILTERS

COMING ATTRACTIONS
New Units to be Announced Soon

AGILE'S Plastic Ductwork Costs Less... Has Longer Service Life Than Stainless Steel



AGILE'S Plastic Installation

- **Cost** **$491.00**
- **Service** ..... **Still in use after 3 years**

Stainless Steel Installation

- **Cost** **$581.00**
- **Service** ..... **only 16 months**

PROBLEM: This company was using a type 19-9 stainless steel stack for venting the fumes on a sulphuric acid tank. This stack was installed at an original cost of $581, was no longer serviceable after 16 months because of corrosion.

SOLUTION: The company replaced the stainless steel installation with a plastic structure of equal dimensions for $491.00. The new stack still in perfect condition, has a life expectancy of many, many years.

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CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before December 15, 1956, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

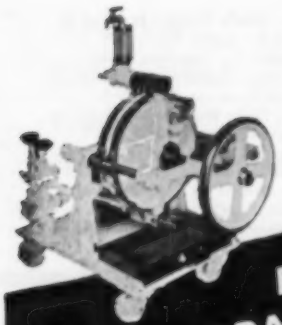
Member

Allen, Howard I., *Oakland, Calif.*
Ankeney, James H., *So. Charleston, W. Va.*
Berndt, Joseph P., Jr., *Webster Groves, Mo.*
Brooks, Maurice E., *Great Neck, L. I., N. Y.*
Cooper, Alvin G., *Whittier, Calif.*
D'Apice, John, *New York, N. Y.*
DeBerardinis, Albert J., *Haddonfield, N. J.*
Devore, Abe, *Newark, N. J.*
Doherty, Louis A., *Naugatuck, Conn.*
Dyck, William J., *Torrance, Calif.*
Geer, John A., *Boulder, Colo.*
Graybeal, Paul E., *No. Plainfield, N. J.*
Hawkins, John C., *Sharon, Mass.*
Jacobs, William L., *Frederick, Md.*
Karns, Robert D., *Pittsburgh, Pa.*
Kelchner, Burton L., *Wheat Ridge, Colo.*
Kirk, Michael M., *Hopewell, Va.*
Lawton, Frank H., *Ardmore, Pa.*
Medl, R. C., *Glens Falls, N. Y.*
O'Brien, W. F., *Wilmington, Del.*
Odle, John D., *Catonsville, Md.*
Pace, Benjamin S., *Baton Rouge, La.*
Pilat, Theodore J., *Brookfield, Ill.*
Powers, J. M., *Summit, N. J.*
Schay, S. Rus, *Middletown, N. Y.*
Springer, R. A., *No. Madison, Ohio*
Trapp, John H., *Newtown, Ohio*
Voglica, Nicholas J., *Port Neches, Tex.*
Vaci, Joseph J., *Cambridge, Mass.*
Williams, F. Campbell, *Rio de Janeiro, Brazil*
Wride, W. James, *Bartlesville, Okla.*

Associate Member

Abeyta, Oscar R., *Trona, Calif.*
Abrams, Edward Hugh, *Forest Hills, N. Y.*
Ackerman, Norman, *Queens Village, N. Y.*
Ackermann, William, *Cambria Heights, L. I., N. Y.*
Acrivos, Andreas, *Berkeley, Calif.*
Advani, P. S., *Port Neches, Tex.*
Alexander, Paul, Jr., *Sandusky, Ohio*
Allen, Maurice, *Baytown, Tex.*
Ault, Bromwell, *New York, N. Y.*
Bierman, Sidney R., *Aruba, N.W.I.*
Blecherman, Sidney, *Brooklyn, N. Y.*
Blendermann, Walter H., *Rosedale, N. Y.*
Bondra, Max A., *Shaker Heights, Ohio*
Book, James L., *Lawrence, Kan.*
Borie, Edward T. L., *New Orleans, La.*
Bosworth, E. Ward, *University City, Mo.*
Broughton, Amos W., Jr., *Somerville, N. J.*
Brown, Gilbert M., *Jacksonville, Fla.*
Carrell, Harry L., *Kingsport, Tenn.*
Cater, N. E., *Mobile, Ala.*
Chalawsky, Fred, *Brooklyn, N. Y.*
Chamberlain, Harry V., *Idaho Falls, Idaho*
Clement, John Lloyd, *Green Cove Springs, Fla.*
Cochran, Jerry, *Buffalo, N. Y.*
Cool, Ralph E., *Richmond, Va.*
Cooper, Richard C., *Grand Haven, Mich.*
Cutting, Albert Edward, *East Weymouth, Mass.*
Dawson, Perry P., Jr., *Angleton, Tex.*
De Clue, Robert T., *West Newton, Mass.*
Demmel, Edward J., *Pitman, N. J.*
De Lessio, Carmine T., *Brooklyn, N. Y.*
Dey, Harold L., Jr., *Columbus, Neb.*
Diestelow, Lee W., *Harvey, Ill.*
Dietz, John W., *Winona, W. Va.*
Di Fonzo, Joseph Paul, *Somerville, Mass.*
Dimick, Donald B., *Midland, Mich.*
Does, Fred J., Jr., *Kenilworth, N. J.*
Dougherty, Joseph P., Jr., *Clifton, N. J.*
Durler, Charles N., *Pitman, N. J.*
Eberhardt, Martin M., *Tonawanda, N. Y.*
Eisenbach, Robert L., Jr., *Baton Rouge, La.*
Ellis, William J., *Midland, Mich.*
Erdman, Andrew, Jr., *Elmhurst, L. I., N. Y.*
Esslgroth, Herbert T., *Mineola, L. I., N. Y.*
Esserman, Donald, *Brooklyn, N. Y.*
Fanning, Herbert H., *Cliffside Park, N. J.*
Farst, James R., *Zanesville, Ohio*
Fetzer, Richard C., *Long Beach, Calif.*
Fitch, Fredric B., *Woodbury, N. J.*
Fleming, Joseph W., *West Newton, Pa.*
Ford, Harry E., *Cleveland, Ohio*
Forgensi, Rudolph, *Akron, Ohio*
Fougerousse, Louis H., *Baton Rouge, La.*
Frazier, George C., Jr., *Fredericksburg, Va.*
Friend, William L., *Long Island City, N. Y.*
Frint, W. R., *Green River, Wyo.*
Gontcharuk, Joseph, *Brooklyn, N. Y.*

(*Continued on page* 132)



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Equipped with 3 gpm pump and electric motor. Stainless steel or bronze nickel plated circulatory system. Holds 4 to 8, 12-1/4" dia. disks.

Ertel Portable SMALL CAPACITY FILTERS

EFS-B filter is recommended for small batches where sludge or filter aid is required. Also advantageous because no rubber washers are required . . . the asbestos sheets form their own seal. The EBW filter is ideal for high polishing filtration using filter pads.

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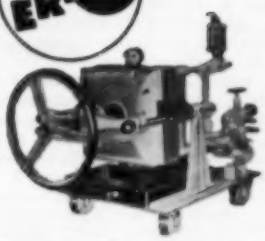

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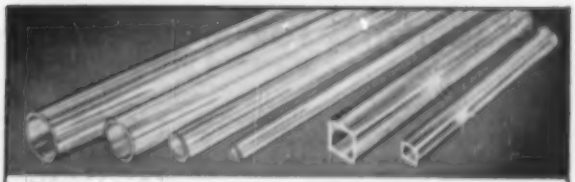

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NEW "SAFEGUARD" ROTAMETER BULLETIN
Gives Step-by-Step Sizing Instructions

Immediately available on request, new SK Bulletin 18RG provides valuable information for anyone who must measure fluid rate-of-flow accurately and safely. The bulletin describes SK's line of "Safeguard" Rotameters—includes complete data on application, construction, materials available, installation, and operation.

User benefits are recorded in detail. Of great value are the simplified, step-by-step instructions for sizing and selecting Rotameters for liquid and gas rate-of-flow measurement. Capacity tables are included.

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CANDIDATES FOR MEMBERSHIP IN A.I.Ch.E.

(*Continued from page* 130)

Goodman, Harold, *Flushing, N. Y.*
Gordon, Harry E., Jr., *Wilmington, Del.*
Grandio, Philip, Jr., *Texas City, Tex.*
Greosel, John E., *Keneth, N. J.*
Green, Robert E., *Whiting, Ind.*
Gruber, Michael, *Brooklyn, N. Y.*
Gusemon, James R., *Perryopolis, Pa.*
Guzman, Guido D., *Tierra Blanca Ver, Mexico*
Hajjar, Raja, *Columbus, Ohio*
Hansen, David, *Raleigh, N. C.*
Haynes, Frank J., Jr., *Hamden, Conn.*
Helander, Robert E., *Buena Park, Calif.*
Herrick, Elbert C., *Boothwyn, Pa.*
Hill, J. Carl, III, *Columbus, Ohio*
Heikkinen, Henry W., *Minneapolis, Minn.*
Hoffman, James Z., *Brookfield, Ill.*
Hooper, William B., *Texas City, Tex.*
Houseman, Evon Kenny, *Parkersburg, W. Va.*
Hummel, Jack L., *Pasadena, Tex.*
Jakobson, Kurt, *New York, N. Y.*
Johnson, Doris C., *Allentown, Pa.*
Jones, O. Reps, *Baton Rouge, La.*
Kaku, Yukio John, *Berkeley, Calif.*
Karp, Herbert E., *New Haven, Conn.*
Kaznoff, Alexis I., *San Francisco, Calif.*
Laffert, Frederick William, Jr., *Lawrence, Mass.*
Lilburn, Jack H., *Pasadena, Tex.*
Lipscomb, Thomas G., II, *Baytown, Tex.*
Loke, Richard A., *Milwaukee, Wis.*
Lueck, Robert E., *Middletown, N. Y.*
Maier, William H., *Painesville, Ohio*
Marino, Pasquale A., *Dorchester, Mass.*
Masters, Arthur I., *Anderson, Ind.*
Mathews, Stanley F., *Hickman Mills, Mo.*
Matthews, James Edwin, *Nahant, Mass.*
McGill, Paul L., *Pittsburgh, Pa.*
McLeod, James E., *Butte, Mont.*
McTyier, Robert B., Jr., *Wilmington, Del.*
Messeri, Roland, *Philadelphia, Pa.*
Most, Stuart L., *Greenfield, Mass.*
Mussey, Richard A., *Falls Church, Va.*
Nadler, Murray, *New York, N. Y.*
Nahill, George F., *Wilmington, Del.*
Neef, William I., *Omaha, Neb.*
Nikodem, John S., Jr., *No. Augusta, Ga.*
Ormiston, William G., *Bartlett, Ohio*
Oubre, Carroll L., *St. Martinville, La.*
Pettigrew, Buddy G., *Midland, Mich.*
Phelps, Carl Waller, *Cincinnati, Ohio*
Phillips, Martha Louise, *Cumberland, Md.*
Pings, Cornelius J., Jr., *Stanford, Calif.*
Poole, Donald Richards, *Southboro, Mass.*
Posorow, Edward, *Malverne, N. Y.*
Richardson, R. C., *Memphis, Tenn.*
Rizzo, Joseph J., *Philadelphia, Pa.*
Roach, Ted L., *Kingsport, Tenn.*
Robinson, David W., *Youngstown, Ohio*
Rosen, Ralph, *Flushing, N. Y.*
Rubel, Morton, *Brooklyn, N. Y.*
Rumsey, Donald W., *Moncleva, Ohio*
Schlachter, Adolph F., *Brooklyn, N. Y.*
Schnaible, Harold W., *Pittsburgh, Pa.*
Schwarer, Richard F., *Janesville, Wis.*
Schwartz, John A., *Maspeth, N. Y.*
Seidman, Norman, *Lancaster, Pa.*
Senula, Gerhard K., *Sewell, N. J.*
Sheets, MacArthur, *Cincinnati, Ohio*
Shepardson, Jed P., *Midland, Mich.*
Lee, Bernard Shing-Shu, *Jamaica, N. Y.*
Shuttleworth, Edwin I., *Chicago, Ill.*
Silber, Irwin, *Middle Village, N. Y.*
Silvus, Robert F., *Austin, Tex.*
Simmons, Robert L., *Stoneham, Mass.*
Simonsen, James R., *Midland, Mich.*
Swier, George J., *Jersey City, N. J.*
Sklepkowycz, Oleh, *Brooklyn, N. Y.*
Skogen, Duane B., *Ponca City, Okla.*
Snyder, Glenn E., *So. Charleston, W. Va.*
Stark, Robert L., *Huntington, W. Va.*
Stauverman, Edward, Jr., *Munster, Ind.*
Stenberg, Jim, *Pensacola, Fla.*
Stewart, J. Thomas, Jr., *Freeport, Tex.*
Swaab, M. Mark, *New York, N. Y.*
Swindell, Charles W., Jr., *Norfolk, Va.*
Tarmy, Barry L., *Cranford, N. J.*
Teplitzky, Gerald, *Brooklyn, N. Y.*
Traynor, John J., Jr., *Brooklyn, N. Y.*
Trexler, Jay E., *Toledo, Ohio*
Trombley, Gene Leon, *Texas City, Tex.*
Van Atta, John R., *Fayetteville, N. Y.*
Van Gorder, Jan H., *Sycamore, Ill.*
Varanelli, Andrew D., *Cincinnati, Ohio*
Vass, Maurice P., *Woodstown, N. J.*
Weisel, John W., *Canton, Ohio*
Weisz, John J., *Columbus, Ohio*
Whatley, M. E., *Oak Ridge, Tenn.*
Wilson, Walter V., III, *West Palm Beach, Fla.*
Witt, Henry J., *Queens Village, N. Y.*
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Yanowitz, Herbert, *Brooklyn, N. Y.*

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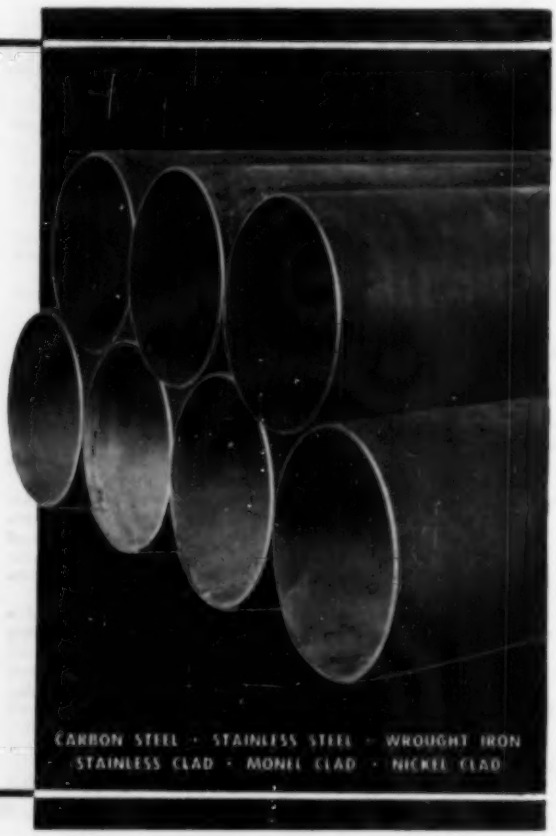

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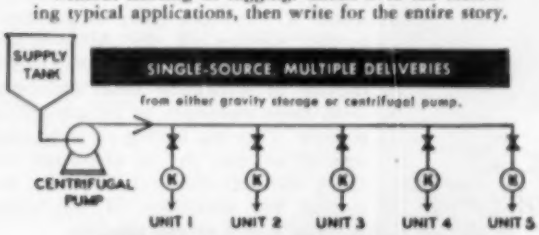
KATES direct-acting regulators combine with inexpensive centrifugal pumps or gravity feeds for precision control of blending, liquid circuits, process additives, or coolants—more reliably and at less cost than comparable control systems. Pressure jumps or drops of 125 psi, either upstream or down, are compensated internally—without hunting or lagging. Check over the following typical applications, then write for the entire story.



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from either gravity storage or centrifugal pump.

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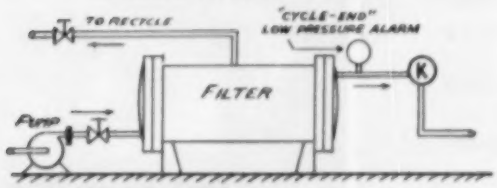
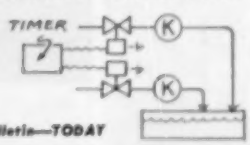
keeps filtration rate at desired point despite steady build-up of filter cake; no valve jockeying!



BATCH PROCESS MEASUREMENT

with nothing more than a timer and solenoid valves feeding through Kates regulators!



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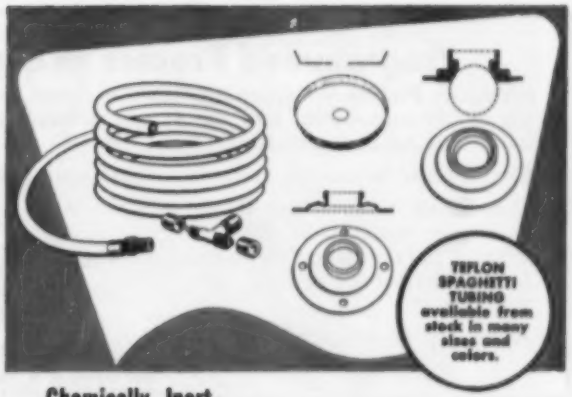

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Beats Corrosion and Fatigue

If your problem involves highly corrosive chemicals and temperature extremes, the opportunities that TEFLON flexible Thin Wall Tubing offers the chemical field is without parallel.

Teflon possesses a remarkable combination of properties unmatched by any other single material. Characteristics such as complete chemical inertness, resistance to temperatures (ranging from —450° F to 500° F) and corrosion, high dielectric strength, low co-efficient of friction and toughness, makes Teflon the only material that will give satisfactory performance.

Teflon Flexible Thin Wall Tubing is available from stock in many sizes and colors.

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In Thin Sections and Shapes . . .

Cup, Ball or Shaft Seals, Gaskets, Washers or Diaphragms—engineered to meet exact requirements and dimensions—provides exceptional performance and long life . . . lowers maintenance, cuts replacement costs and downtime. Because of the low-friction characteristics of Teflon, the torque required to turn shafts or stems is minimized.

If you are experiencing trouble with a part now made of rubber, leather or other sealing materials which will not withstand severe service conditions — a further investigation of Custom Molded Teflon parts (in thin sections for flexibility) will provide your answer.

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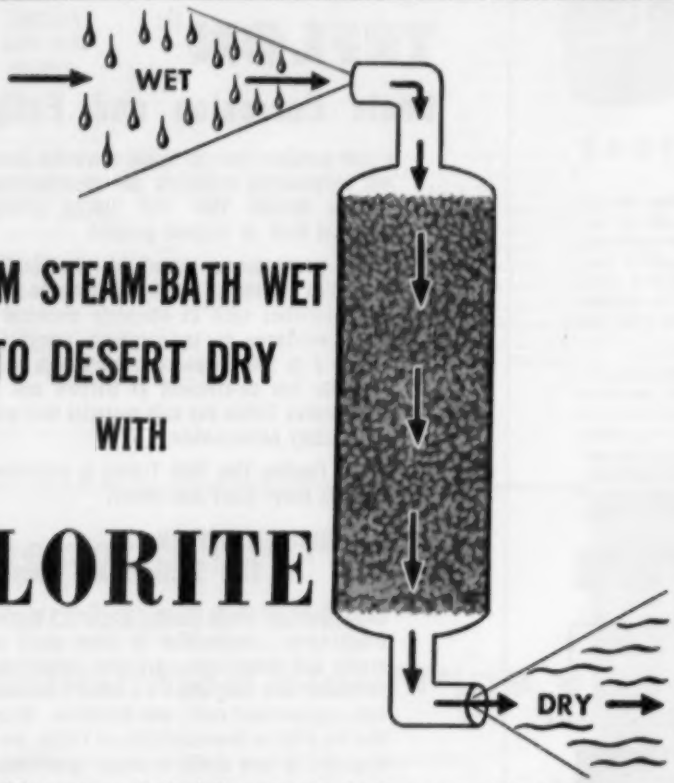

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News of the Field
FROM LOCAL SECTIONS

(Continued from Page 127)

better teaching, the need for teachers, particularly in science, to keep up to date, and the necessity of giving high school teachers freedom from mass production teaching methods. B. Edwards, professor of education at the Univ. of California; R. H. Eastman, professor of chemistry education at Stanford; A. Taylor, Balboa High School; and E. Roberts, Polytechnic High School, formed the panel. N. Easter moderated

Mexican Plant Studied

Annual Rio Grande Valley meeting of the **Coastal Bend Section** (*O. L. Culberson*), held August 24-25, began with a long tour of the modern gas absorption and refining facilities of Petroleos Mexicanos (Pemex) near Reynosa, Tamaulipas, Mexico. The Pemex absorption plant has a capacity of 300 million st. cu. ft./day of natural gas, while the refinery processes 10,000 bbls./day of crude. Particularly notable at the Pemex plant was a guiding philosophy of service to the employees. Next morning the section toured the gas absorption plant of the Delhi-Taylor Corp. in Texas.

"Molecular sieves," a relatively new product developed by the Linde Corp., whose R. A. Jones spoke to the September meeting of the **Alton-Wood River Section** (*R. W. Keating*), are capable of separating small molecules from large molecules by an adsorption process. They are finding an increasing number of uses in the petroleum refining and petrochemical industries, including the possibility of upgrading gasoline 4 or 5 octane numbers.

Thomas Griswold, Jr., now in his 60th (!) year with Dow Chemical Co., has been named honorary chairman of the Midland Section (R. B. Jones). Here, D. L. Katz, Univ. of Mich. and a director of A.I.Ch.E., presents the scroll naming Griswold honorary chairman. "T.G.", as he is known at Midland, has been Chief Engineer, head of the Patent Dept., and Consulting Engineer in his long service with the company.

Space Travel

As a specialist in high-altitude physics, T. M. Donahue, Univ. of Pittsburgh, discussed the problems and potential of Satellites and Space Travel before the October meeting of the **Pittsburgh Section** (*G. Karnofsky*).

Increasing Membership

The **St. Louis Section** (*L. F. Brennecke*) underwent a critical reorganization recently and came up with methods for increasing membership in its section. A contact man was appointed for every plant in the area. His job is to talk to and interest every chemical engineer who is not a member in both the local section and A.I.Ch.E. The publicity committee cooperates by sending meeting notices to non-members. As another measure to arouse interest and familiarity, a three-man committee represents the local section on the St. Louis Engineers Joint Council. This last is also under the heading of community service, as is the provision of speakers for the local high schools and universities.

The Engineering of Meaning

The engineer can solve most of his public relations problems, improve the acceptance of what he does, improve his talents and his reward, by properly engineering what he means when he speaks or writes. Speaking to the June meeting of the **Southern California Section** (*R. D. Sheeline*) Don Sweeney, Western Oil and Gas Association, emphasized four points for successful speaking: 1) cast your talk or writing in terms of the interest of the listener or reader; 2) use simple language which your audience knows; 3) avoid using your technical jargon or shorthand; and 4) clearly show what advantage will accrue to the audience from the subject of your talk.

WHITMAN CONTINUES TALKS ON INTERNATIONAL COOPERATION IN ATOMIC SCIENCE

Two more local sections heard Walt Whitman, A.I.Ch.E. president, report on the achievements and lessons of the Geneva Atoms for Peace Conference. The October meetings of the **Central Ohio Section** (*W. W. Ellis*) and the **East Tennessee Section** (*R. F. Hunt, Jr.*), heard Whitman emphasize that the experience of free interchange among professionals when the Iron Curtain was raised in the area of peaceful atomic energy has instilled new hope throughout the world and disclosed a new technique for cooperation which political leaders should foster.

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people

Richard Fiske Shaffer is retained as a chemical consultant by Gifford-Wood Co., Hudson, N. Y. He served as professor and chairman of the department of chemical engineering, Pratt Institute, for the past ten years.

David H. Killeffer, Crestwood, N. Y., author and publicist, has won the first James T. Grady Medal, given by the A.C.S. for distinguished reporting of chemistry, chemical engineering and related fields. For more than 30 years he has been a leader in the interpretation of chemical progress to the layman.

Emanuel Singer is on a special one-year assignment at Shell Oil's new two-stage catalytic cracking unit at Anacortes, Washington.

Burton V. Coplan is appointed to the post of silicon project supervisor in General Electric's chemical development Dept., Pittsfield, Mass.

Herbert Trotter, Jr., formerly vice president of engineering and research for The Sharples Corp., Philadelphia, is named executive vice president. Since joining the firm in 1956, Dr. Trotter has headed research and development of centrifugal processes as well as other projects of the Sharples Research Laboratories.

Onorio Colucci is appointed a project engineer in the chemical division of Pittsburgh Coke and Chemical.

A.I.Ch.E. President **Walter G. Whitman** has been elected an honorary member of The South African Institute of Mining and Metallurgy, for the year ending June 30, 1957.

Matthiew F. Callahan joins Pittsburgh Coke & Chemical, engineering development section, as a chemical engineer. He was formerly with B. F. Goodrich.

W. A. Wilson becomes plant manager of the new Orange, Texas, butadiene plant of the Firestone Tire & Rubber Co.

The appointment of **Ben Chizeck** as chemical engineer in the chemical division is announced by Pittsburgh Coke and Chemical Co., where he specializes in process improvement.

J. D. Fitzpatrick becomes manager of the newly created basic research section of Emery Industries, Cincinnati.

Alfred Iddles, president of the Babcock & Wilcox Co., is elected president for the forthcoming year of the Atomic Industrial Forum. He succeeds **Walker L. Cisler,** president of Detroit Edison Co., who served as president of the Forum since that organization's inception in April, 1953.

Oscar J. Swenson elected to the board of directors of the Carwin Company, North Haven, Conn. He was named vice-president for engineering of the Primary Aluminum Division of Olin Mathieson Chemical Corp. in 1955, and early this year resigned to return to private consulting practice.

Albert J. Rothman joins Columbia University where he is to be senior engineer in the engineering research center and research associate in the chemical engineering department.

James R. Britt is the new manager of the chemical plants division of Procon, Incorporated, Des Plaines, Ill.

Election of **O. V. Tracy** as a vice president of Esso Standard Oil Company is announced. He will continue to serve as a member of Esso Standard Oil's board of directors and of the executive committee, with board-level responsibility for both the manufacturing and chemical products departments.

Richard A. Rammer and **William A. Shire** join Maumee Chemical Co., Toledo, as process engineers.

C. William Roos, Monsanto, St. Louis, is promoted to group leader in charge of engineering research in the organic chemicals division.

At Brown Fintube, Elyria, Ohio, **Douglas Towers** becomes chief thermal engineer.

Norman Banta becomes superintendent of the technical department of the Pure Oil Co. Smiths Bluff Refinery, Nederland, Texas. **William E. Norris** is transferred to the home office of Pure Oil in Chicago, where he is assigned to the operating division of the refining department.

(*Continued on page* 138)

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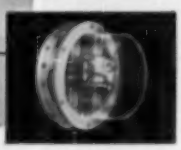

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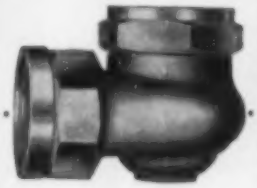

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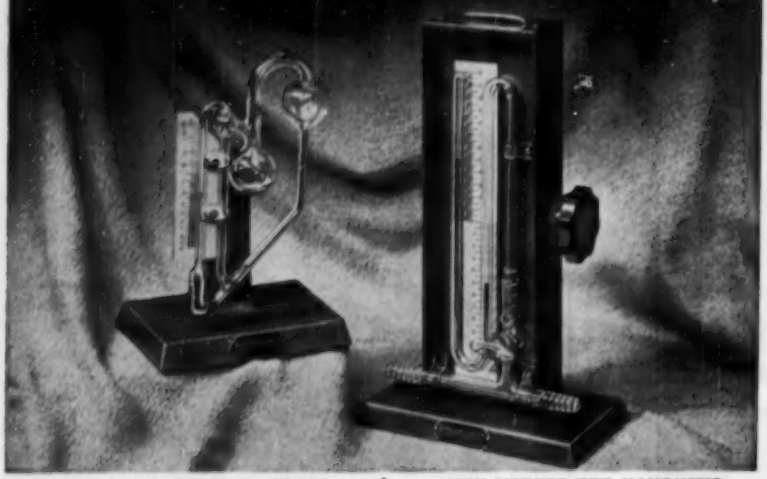

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D. F. Jurgensen fills the new post of vice president in charge of development and research for the Blaw-Knox Co., Pittsburgh. Jurgensen has been director of engineering and development for Congoleum-Nairn, Inc.

The University of Pennsylvania appoints **Lee C. Eagleton,** formerly with Rohm and Haas, and **R. Wayne Houston,** formerly with the U. of New Hampshire, associate professors of chemical engineering.

Lauren B. Hitchcock resigns as president and managing director of the Air Pollution Foundation, Los Angeles, to return to private practice as a management consultant in industrial research and development.

George W. Preckshot, associate professor of chemical engineering at the U. of Minnesota, and research engineer **Jay Nouri** have won the 1956 Fatty Acid Producers' Council Award of $500. Their award-winning research produced new data on the solubilities and phase diagrams for oleic, palmitic, and stearic acids, as well as their various mixtures.

Brymer Williams, associate professor of chemical and metallurgical engineering at the U. of Michigan, is serving as chairman of his department in the absence of **Donald L. Katz,** who is on sabbatical leave.

Research engineer **Warren B. Stewart,** formerly with Sinclair Research Labs., Harvey, Ill., is teaching chemical engineering at his alma mater, the U. of Wisconsin.

Henry S. Winnicki becomes president and manager of the Food Machinery and Chemical Corp.'s organic chemicals division with headquarters in N. Y.

H. C. Van Ness is now assistant professor in the department of chemical engineering, Rensselaer Polytechnic Institute.

John C. Robinson becomes commercial fuel manager of the atomic energy division at Sylvania Electric Products, Bayside, N. Y., and has responsibility for production of nuclear fuels for commercial applications.

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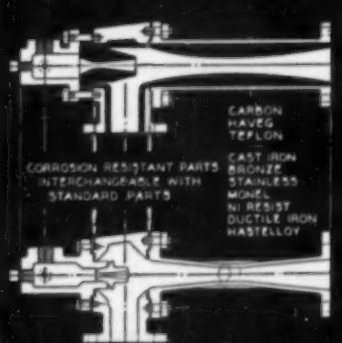

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Howard I. Cramer named director, technical liaison, for Pennsalt Chemicals, Philadelphia. He will further the company's interest in foreign technological developments and the exchange of scientific information.

R. L. Olson is appointed instructor in chemical engineering at Oregon State College.

Paul J. Flory is chosen to head Mellon Institute's investigational activities as executive director of research. Flory, now associated with Cornell U., will join the Institute on a part-time basis until the summer of 1957. In this post, which has been established since the recent retirement of Edward R. Weidlein as president, Flory will be responsible for mapping the research future of the Institute.

George C. Szego becomes manager of a study group in the advanced propulsion systems section, aircraft gas turbine division, General Electric Co. For the past eight years Szego was head of the chemical engineering department at Seattle U.

Richmond P. Mosher is appointed to the staff of the Tonawanda, N. Y., laboratories of Linde Air Products, where he will work with the research group on molecular sieves. **John G. Polcari** is transferred from the N. Y. laboratories to the silicones division of Union Carbide and Carbon, Sisterville, West Virginia, as a production engineer in the polymers department. **Erwin G. Meeh, Jr.,** returns from a tour of duty with U. S. Army Ordnance Corps to the process development group of Tonawanda Labs.

John R. Corsberg joins Phillips Petroleum Co., Atomic Energy Division, at the Materials Testing Reactor, Idaho Falls, Idaho.

W. Standish Miller resigns as vice president of Gonzalez Chemical Industries, Inc., Puerto Rico, to return to consulting work at Fullerton, California, on production of heavy chemicals.

Appointment of **Fred W. Evans** as assistant to the president of Surpass Petrochemicals Ltd., Scarboro, Ontario, and Alox Corp. of Niagara Falls, N. Y., is announced.

(Continued on page 149)

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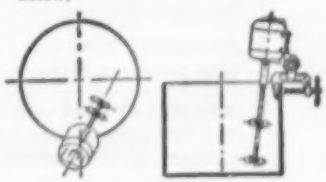

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The most desirable qualifications will include five years of industrial experience, preferably in fluid mechanics, with broad knowledge of both theory and practice in the field of agitation and mixing. Duties will include: determinations of agitation requirements for chemical reaction, heat and mass transfer, dispersion, blending and other operations; equipment evaluation; selection, specification, and design; modification of existing equipment for unusual or special agitation problems; trouble-shooting; and start-up assistance.

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Graduate engineer with three to ten years' experience with bulk or package handling systems and equipment. The successful applicant will be expected to have engineering knowledge of belt conveyors, bucket elevators, screw conveyors, storage bins, chutes, hoppers, and feeders. Familiarity with pneumatic conveyors or mobile handling equipment is desirable. Duties include providing consultation on existing equipment, selection of new equipment, and the development and execution of major materials handling engineering programs.

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November 25-26-27-28
To arrange an appointment with our technical representative, please call
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PEnnsylvania 6-5096

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Sun-Mon-Tues-Wed
December 9-10-11-12
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...THROUGH CHEMISTRY

Or you may send complete resume, including details of education and experience to:

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E. I. du Pont de Nemours & Co., Inc.
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CHEMICAL ENGINEERS

American Viscose Corporation, a chemical-process industry, has some **permanent positions open now for chemical engineers.** To qualify you need a B.S. or M.S. degree from a recognized institution, and, preferably, 3-5 years of experience in process development, product-improvement studies, or chemical engineering 'trouble-shooting' for manufacturing.

The location is in suburban Philadelphia (Marcus Hook) at the **Research and Development Division,** or at one of our seven plants in Pennsylvania, West Virginia, and Virginia.

AVISCO

These openings are technically challenging and offer good advancement opportunities. Interested candidates are invited to submit résumés of personal data, educational history, and work experience to:

Personnel Recruitment Department

AMERICAN VISCOSE CORPORATION

1617 Pennsylvania Boulevard

Philadelphia 3, Pennsylvania

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Required for responsible positions in our sales and engineering departments. Engineering degree and five years' experience on tubular heat transfer thermal and mechanical design desirable. Other positions open for engineers with pressure vessel and column experience.

Contact J. R. Pierael, Personnel Manager

Downingtown Iron Works, Inc.
Downingtown, Penna.

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Permanent positions of responsibility, with excellent starting salaries, are open to graduate Chemical Engineers having 5-10 years' experience in:

Process Engineering
Economic Studies
Process Design and Construction

Company is among the leaders in manufacture of carbon dioxide, oxygen, acetylene, hydrogen and medical gases and is engaged in the largest expansion program in its sixty-seven year history.

Our Staff Project Engineers gain experience which qualifies them for future executive positions within the organization. Submit complete resume including history of earnings and salary requirements to

Personnel Department
LIQUID CARBONIC
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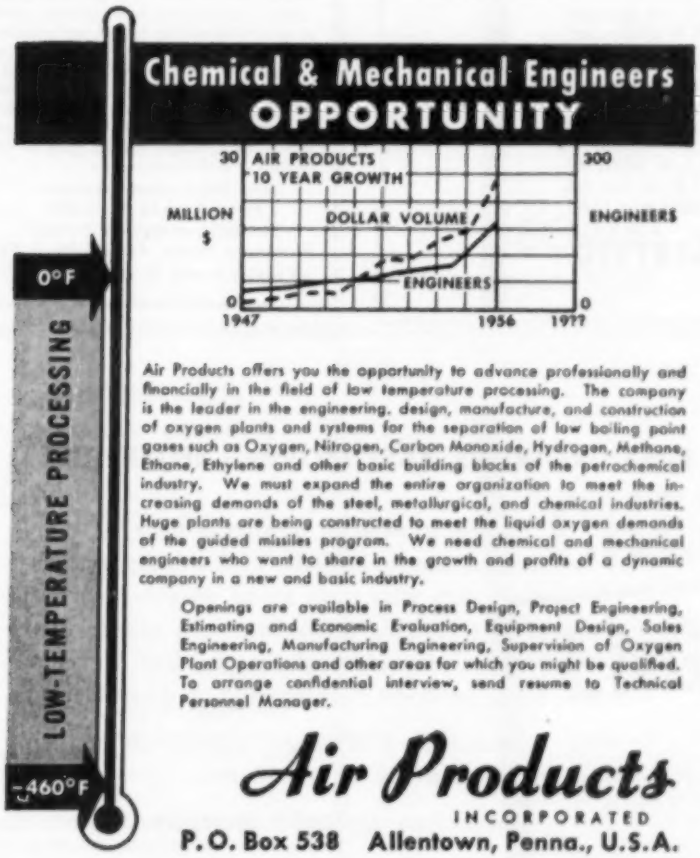
Chemical & Mechanical Engineers OPPORTUNITY



Air Products offers you the opportunity to advance professionally and financially in the field of low temperature processing. The company is the leader in the engineering, design, manufacture, and construction of oxygen plants and systems for the separation of low boiling point gases such as Oxygen, Nitrogen, Carbon Monoxide, Hydrogen, Methane, Ethane, Ethylene and other basic building blocks of the petrochemical industry. We must expand the entire organization to meet the increasing demands of the steel, metallurgical, and chemical industries. Huge plants are being constructed to meet the liquid oxygen demands of the guided missiles program. We need chemical and mechanical engineers who want to share in the growth and profits of a dynamic company in a new and basic industry.

Openings are available in Process Design, Project Engineering, Estimating and Economic Evaluation, Equipment Design, Sales Engineering, Manufacturing Engineering, Supervision of Oxygen Plant Operations and other areas for which you might be qualified. To arrange confidential interview, send resume to Technical Personnel Manager.

Air Products
INCORPORATED
P.O. Box 538 Allentown, Penna., U.S.A.

Opportunities in Research & Development

We also need engineers who are interested in applying the principals of thermo dynamics, fluid flow, heat and mass transfer, vapor-liquid equilibria, etc. to the solution of complex new problems in low temperature technology including distillation, adsorption, absorption, physical property experimentation, analytical methods and instrumentation, process development, pilot plants, equipment development including process apparatus and machinery items such as turbines, pumps, expanders, compressors and many other interesting and classified projects.

CHEMICAL ENGINEERS

Foreign Employment

For career assignments in technical service and research and development work in a large modern refinery installation in Saudi Arabia. Excellent opportunities for diversified experience and advancement assured by complexity of present installation and future expansion.

Liberal salary plus allowances and all-inclusive benefits. Opportunity to travel on long vacations and live in modern community with complete facilities including extensive recreation.

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Please include telephone number.

Recruiting Supervisor, Box 175

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505 Park Avenue

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Develop High Temperature Materials for Nuclear Flight

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At least 8 to 10 years experience is required, involving non-metallic inorganic materials for use at high temperatures. (If directly related, time spent in obtaining an advanced degree may be considered part of this experience.) Applicant must be a graduate physical chemist, metallurgical engineer, or ceramic engineer, preferably with Ph.D. or equivalent.

Publication of research results in the appropriate classified or open literature is encouraged.

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Men with 0-15 years' experience in their profession will be considered.

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New York Personnel Dept. T.
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30 East 42nd Street
New York 17, New York
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CHEMICAL ENGINEERS

Major Oil Company has openings for Chemical Engineers in several phases of process engineering. Locations near New Orleans and south Arkansas. Attractive salary and benefits program.

In reply give age, education, experience and salary expected.

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Write, giving a complete resume of your education, experience and personal data to:

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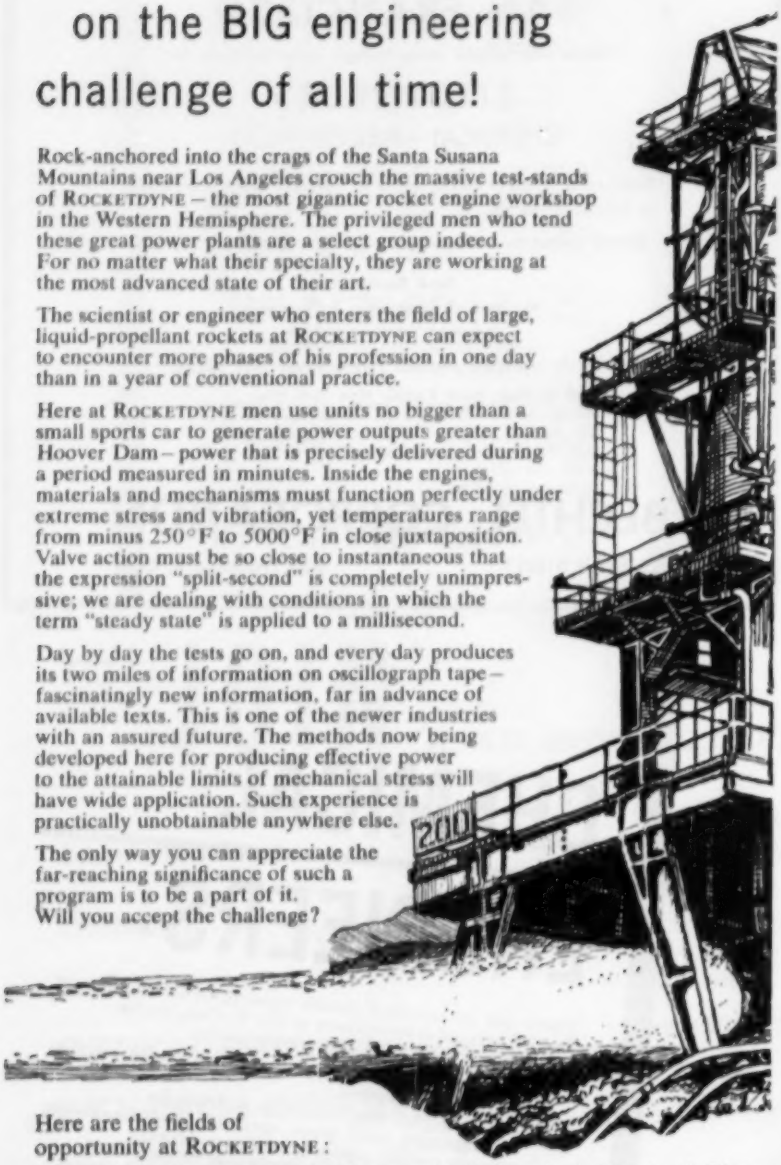

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INTERESTING BOOKLET. Facts about rocket engines and engineering. Send for your personal copy of "The Big Challenge." Write: A. W. Jamieson, Rocketdyne Engineering Personnel Dept. CEG, 6633 Canoga Avenue, Canoga Park, Calif.

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Our Process Engineering Department has opportunities for several experienced engineers who wish to follow their preferred fields in petroleum refining or large volume petrochemical processing.

Assignments will be primarily process design and economics – determination of overall process requirements, selection of processing steps, and economic evaluation of processes. Other work may include market analysis, industrial surveys, and technical assistance to sales.

Write to the head of our Personnel Department, Mr F B Stratford.

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Unusual opportunity to do stimulating work in Chemical Engineering or Reactor Technology on pilot plant or laboratory scale. Several years' experience desirable in reactor water technology, reactor economics, or radiochemical techniques. Opportunities to direct projects or work under experienced men. These are permanent positions offering professional and personal growth. Please send résumé to:

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Advertisements in the Classified Section are payable in advance at 20¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section agree that all communications will be acknowledged; the service is made available on that condition. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

SITUATIONS WANTED

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CHEMICAL ENGINEER—five years' experience product and process development. Seeking responsible position in development or plant operations. Offer enthusiasm, technical and supervisory competence. Age 26, family. Box 2-11.

CHEMICAL ENGINEER—Sc.D., with special interest in plastics and plastics-paper combinations. Long record in research, unit plant, lab. management, project planning, supervision of manufacture, sales service. Desire greater responsibilities. Box 3-11

(*Continued on page* 148)

ESSO ENGINEERING IS EXPANDING

CHEMICAL ENGINEERS NEEDED

Career openings available in long range expansion program. Work involves process planning, economics, design, and occasional field follow-up.

Prefer men of high scholastic rating and with one to seven years' experience. There are also a number of openings for very recent graduates. Both Bachelors and Masters degree positions are available. Salary commensurate with experience and qualifications.

If you are interested in an opportunity for growth and promotion with a leader in the petroleum industry, write today giving full details of education, experience, salary desired, availability date and references.

All inquiries will be considered promptly and held confidential.

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Employee Relations-C
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Major oil company with plants located in Texas, Virginia, Arkansas, and Louisiana. Major Research and Development activities located in Texas City, Texas.

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required for process design, process development and technical service to refining and chemicals manufacture. BS, MS, PhD, 0-10 years' experience.

Send résumé to
Administrative Director
Research & Development Dept.
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With three to six years experience

Several qualified process engineers can broaden their professional responsibilities in our Process Engineering Department. They will design a wide variety of plants for petroleum refining and large volume petrochemical processing.

Assignments range from complete integrated refineries and chemical plants through all types of individual process units. The work includes heat and material balances, and computations for unit operations such as fractionation, heat-transfer, absorption and extraction.

Fine facilities, top salaries, new retirement plan. Write to the head of our Personnel Department, Mr F B Stratford.

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Positions available for

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Write to Technical Personnel Department

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with theoretical interest and background applicable to fissionable materials.

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commensurate with ability and experience.

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SITUATIONS WANTED

A.I.Ch.E. Members

(*Continued from page 147*)

CHEMICAL ENGINEER—member ROSTER OF AMMUNITION "KNOW-HOW," twenty years' one plant, desire managerial position nitration processes or nuclear power field. Diversified supervisory experience all phases heavy chemicals manufacture. Box 4-11.

MANAGER—PLANT, DEVELOPMENT, PROCESS ENGINEERING—Chemical Engineer, Michigan 1937, P.E. Registration, age 41, nineteen years' intensive experience chemical operations, organic, inorganic, bulk and fine chemicals. Record of technological improvements, cost reductions, good labor relations. Desire challenging high level position. Box 5-11.

PRODUCTION SUPERINTENDENT — Petrochemicals. Seventeen years' industrial experience. Experienced in plant startups and process improvement, plant maintenance, and union labor. Also in plant development of new products. Prefer southern or western location. Box 6-11.

CREMICAL ENGINEER — B.S.Ch.E., 1942. Fourteen years' diversified experience in oil refinery operations. Particularly qualified to handle new projects and expansions from process design and project engineering standpoints. Desire responsible position with progressive chemical, petro-chemical or oil company. Box 7-11.

people

At the presentation of the first Kettering Award, (l. to r.), Dr. E. G. Bailey, founder and chairman of the Bailey Meter Co.; M. S. Coover, president of A.I.E.E.; Dr. Kettering; and Dean A. A. Potter of Purdue.

Charles F. Kettering was honored with an award from six engineering societies, including A.I.Ch.E., at a luncheon during the Fall General Meeting of the A.I.E.E. He is the first recipient of the award—the Charles F. Kettering Medal—which will be given annually "for creative accomplishments for the benefit of mankind, including discovery, invention, improvement in designs or processes within the relationship of materials and energy." Kettering, the inventor of the automobile self starter and many other important developments, is a former general manager of the General Motors Research Laboratories.

Tennyson Smith becomes a member of the technical staff of Atomics International, Canoga Park, California.

George C. Smith joins Du Pont as research engineer in the Jackson Laboratory, Delaware.

Edward T. Fogg is promoted to research supervisor at Jackson Laboratory in charge of the engineering phases of research on fluorine chemicals such as "Freon" nontoxic refrigerant fluids.

Additions to the staff of the Whiting Research Laboratories of the Standard Oil Company (Indiana) are **Richard R. Kinney, Richard R. Kucia, Habib Labbauf, Manoj Sanghvi,** and **James A. Unnerstall.**

Richard W. Kixmiller, vice president of Celanese Corp. of America, is elected a director of the firm.

B. J. Haley is promoted to assistant manager of the Ashtabula, Ohio, plant of Electro Metallurgical Company.

(Continued on page 150)

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ENGINEERING AND MANUFACTURING APPROACH TO *YOUR* SPECIAL PROCESSING PROBLEMS

- ***Chemical Engineering* DESIGN.**
  A staff of qualified chemical engineers, *accustomed to working cooperatively* with the engineers and management of process manufacturing companies . . . specially trained men whose recognized achievements have resulted in their being retained as consultants on many process installations.
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  A complement of mechanical engineers who pool their specialized abilities in equipment design to *develop in detail the mechanical units* required to economically operate your specific chemical process.
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MIssion 7-0805

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CIrcle 2227

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Birmingham 3-8043

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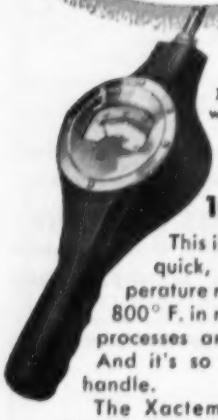

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The Xactemp hand-type pyrometer, Model LT-840, is used with needle thermocouples, ribbon thermocouple, surface tip thermocouple, and other specially designed thermocouples and extension arms. These are easily interchangeable and, without adjustments or recalibration of the instrument, quickly ready it for measuring the surface temperature of stationary and revolving rolls and cylinders, flat and irregular surfaces of molds, dies, etc. in rubber and paper making, plastic materials, rubber, wax, oils, greases, and other semifluid materials.

Handy, compact design makes this Xactemp pyrometer ideal for field service, laboratory, and production-line use.

Write for detailed, descriptive literature on Gordon Xactemp Pyrometers.

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the chemical engineer in

MARKETING

Warren E. Hesler returns to the sales department of Swenson Evaporator Co., division of Whiting Corp., Harvey, Ill. Beginning his career with Swenson in 1947, Mr. Hesler left to take charge of engineering and sales service for Rodney Hunt Machine Co., N. Y. He will be co-chairman of the A.I.Ch.E. Sales Engineering Symposium in Boston.

Edward T. Powers is new director of market research and product development at the Chemstrand Corp., N. Y.

Richard J. Nelson joins General Aniline & Film Corp. as a market research engineer.

Henry J. D'Aragon is advanced to general sales manager of Graver Tank & Mfg. Co., East Chicago, Indiana.

Howard H. Friedel joins U. S. Stoneware Co., Akron, Ohio, as a sales engineer in the process equipment division.

Charles Gardner becomes manager of paint chemical sales for the chemical sales division of Witco Chemical Company, N. Y.

James H. Kane becomes assistant regional sales manager for the N. Y. and New England territories of Archer-Daniels-Midland, Minneapolis.

Necrology

William H. Bower, 92, retired president of the Henry Bower Chemical Manufacturing Co., Philadelphia. Born in Philadelphia, he was graduated from the U. of Pennsylvania in the Class of '85 and became one of the earliest members of the A.I.Ch.E. when he joined in 1908. He served as president of the Manufacturing Chemists' Assn. during the period 1906-1908 and was a member of the executive committee for many years. Mr. Bower took a leading part in the formation of the Compressed Gas Assn. in 1913, serving on its executive board until 1929.

F. W. Zerban, 76, N. Y. Sugar Trade Laboratory, and member of the A.I.Ch.E. since 1924.

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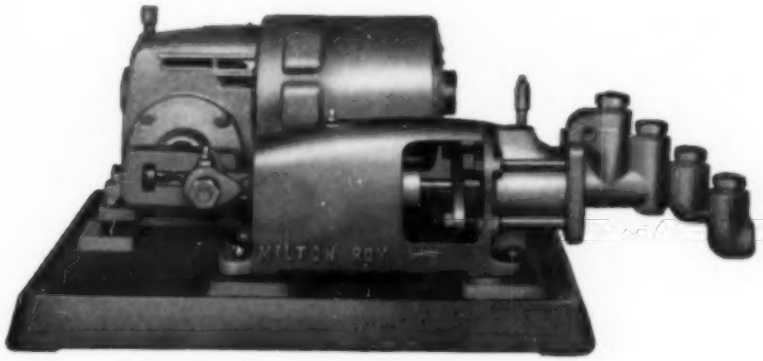
news and notes of A.I.Ch.E.

Mexico City may be the scene of an A.I.Ch.E. meeting & an A.I.Ch.E. local section if the plans begun last month during my visit to Mexico City for the U.P.A.D.I. meeting are successful . . . Below on this page is a picture taken at a luncheon sponsored by A.I.Ch.E. & well attended by a number of important Mexican chemical engineers . . . Plans were to hold a meeting in Mexico the first week in May, 1960 . . . A committee of four was appointed to help carry out the preliminary arrangements for the meeting: Guillermo Ahumada, Cesar Baptista, Ricardo Millares, Jorge L. Oria . . . Other members of A.I.Ch.E. who attended the luncheon were Ralph Morgen, Chairman of the Education and Accrediting Committee; Max Leva, consulting chemical engineer who was by chance visiting one of the local chemical engineers & heard about this attempt; & Walter Lobo, member of Council . . . Lobo in remarks made at the luncheon suggested that owing to the great number of chemical engineers residing in & around Mexico City a local section of A.I.Ch.E. might be begun there . . . The idea was a welcome one & there is a good possibility that there will be a local section in Mexico City before our meeting there . . . Others who attended the luncheon were G. Armando Bayona, Jose I. Bolivar, Vincente Carreto de la Mora, James Cooperman, Jose Mendoza Fernandez, Guido D. Guzman, Guillermo Hidalgo, James M. Hyslop, F. Rafael Illescas, D. W. Johnson, Manuel Lombera y Lugo, G. Manuel Madrazo, & Rodolfo Ruiz Munguia. . . . **U.P.A.D.I. deserves** more explanation . . . The word stands for the Union Panamericana de Asociaciones de Ingenieros & it is one of the several cooperative ventures of your society . . . Every two years representatives from the engineering associations of the Western Hemisphere convene & this recent meeting in Mexico saw all types of engineers from almost every country . . . For a solid week the representatives meet to discuss ways of cooperation between the engineering professions & the various countries . . . The Mexico meeting was no disappointment . . . Many far-reaching programs have been outlined & much progress will probably be reported when we meet next in Montreal in 1958 . . . The interim organization is carried on by an Executive Committee composed of members from various countries. . . The United States representative—appointed by Engineers Joint Council, through which A.I.Ch.E. is represented, is Luis Giorgi of Uruguay . . . Delegates & alternates of A.I.Ch.E. to the conference were Walter Lobo, The M. W. Kellogg Company; Ralph Morgen, Purdue Research Foundation; G. E. Montes, National Petro-Chemical Corp.; and your Secretary. **E.C.P.D.,** another cooperative engineering organization, also met in October . . . This meeting was held in Detroit . . . While the main function of E.C.P.D. seems to be accreditation of courses of engineering & much of the meeting time is given over to it, many other things are also accomplished. For instance, Chuck Roen, who has been chairman of our own Career Guidance Committee, is Vice-Chairman of the E.C.P.D. Guidance Committee & came in from the West Coast to discuss the problems of mutual interest in guiding men just out of college . . . Our representative, W. L. McCabe, was there along with many others on the Education Committee & McCabe, who is also on the preliminary Survey Committee for the Engineering Profession, reported on both committees at the Council meeting in Cleveland on November second . . . Upshot of the study by the survey committee is that, with the engineering societies in E.J.C. & E.C.P.D. contributing about $50,000 in total, financing from foundations, industry, etc., will probably raise the rest of the $1,000,000 necessary for an overall searching analysis of the engineering profession today . . . This survey will be carried on by a paid staff especially hired & trained for the job . . . it will go into every detail of the engineers' training, the type of work they do, how industry uses them, & the economic status of engineers.

F.J.V.A.



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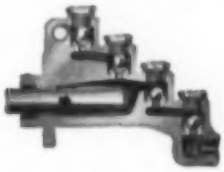

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